A STUDY OF SOIL TOPO-SEQUENCES IN THE STEESE AND WHITE MOUNTAINS OF ALASKA

By

Eric S. Geisler, B.S., M.M.A., C.F.

A Thesis Submitted in Partial Fulfilment of the Requirements

For the Degree of

Master of Science

in

Natural Resource Management: Soils

University of Alaska Fairbanks

School of Natural Resources and Extension

August 2018

APPROVED:

Chien-Lu Ping, Committee Chair

Glen Juday, Committee Member

David Swanson, Committee Member

David Valentine, Director of Academic Programs

Michael Castellini, Dean of Graduate School

ACKNOWLEDGEMENTS

There are many people who have assisted me to make this project not only possible but a successful endeavor. Without their input, encouragement and assistance this study would have been a much more onerous undertaking. First, I would like to thank Dr. Chien-Lu Ping for his patience and persistence through all of the long-distance communications and the delays from my other responsibilities and travels as we worked our way through the program over the last many years. My committee members; Dr. Glen Juday and Dr. David K. Swanson for their support and understanding of a non-traditional student in this program. The Natural Resources Conservation Service (NRCS) staff including; Mark Clark, Nathan Roth, Joshua Paul and Blain Spellman who worked closely with me on the execution of the field work to make this project a reality. The staff of the UAF Plant and Soils Analysis Laboratory in Palmer, Alaska; Gary Michaelson, Lori Wilson and Melissa Dick Parry who guided me and assisted with the analysis of all my samples. To my greatest supporter and unpaid assistant, Penelope Geisler, who helped with the processing of samples at all hours of the night and has set aside many of my regular chores to allow me to engage in the entire Master's program for so many years.

ABSTRACT

The Steese Mountains of Alaska present a complex landscape on which to study soil formation and characteristics in relation to topographic position. The White and Steese Mountains of Alaska are located approximately 70 to 220 km northeast of Fairbanks. Ten toposequences with 3 or 4 sites each were described in the field, sampled, and analyzed in the laboratory in order to determine the relationship between soil morphology and soil-forming factors. Permafrost is discontinuous within the study area and vegetation ranges from tundra on summits to boreal stands of resin birch, quaking aspen, black spruce and white spruce along the lower elevations. There have been many wildfires over time that may have altered the soils and affected the vegetation successional patterns. The processes through which various soil patterns have formed and the unique characteristics of the soils are described here based on field data obtained from both burned and unburned sites. The analysis includes biophysical settings, parent material, texture and nutrient concentrations. Organic horizons were common on most of the transects and play a key role in the depth of the active layer where they exist. Nutrient concentrations are also closely tied to the presence and depth of the organic horizons. Some patterns described in other areas of the boreal region were not observed in this study. There were some soil properties that are not readily described under the current taxonomy protocols which are suggested to be added in a future revision of Soil Taxonomy.

THIS PAGE LEFT BLANK INTENTIONLLY

Table of Contents **Page**

List of Figures **Page**

List of Tables **Page**

Appendices **Page**

INTRODUCTION

The Steese Mountains of Alaska present a complex landscape on which to study soil formation and characteristics in relation to topographic position. They are located approximately 100 km northeast of Fairbanks and stretch northeast about 60 km. The elevation ranges from 300 -1200 m. The study area is part of the Yukon Tanana Highlands of interior Alaska. The mountains are older and thus more rounded than the Brooks Range to the north or the Alaska Range further to the south. While some peaks in the Steese and White Mountains do extend above the vegetation line this study concentrated on the vegetated portions of the mountains in the study area.

In reviewing the various work that has been done regarding the periglacial environment, French (2007), noted that the alpine environment is periglacial by its very nature. He also noted that early studies of periglacial processes were confined to areas of Eurasia, Russia and coastal plains due to the inaccessibility of other areas. One area of limited study French noted was the Barns Mountains of Yukon, Canada which lies just east of the Brooks Range and about 800 km north of this study area. The Barns Mountains have a more arctic climate and a greater maritime precipitation influence as the Barns Mountains catch storm effects from the Arctic Ocean. Extensive work on the geology and distribution of permafrost in Alaska was done by Péwé (1975) but soil profiles were not described in his work.

Soil development rates and soil properties in the transantarctic mountains were studied by Bockhiem and Ugolini (1990a), Bockheim (1990b) and Campbell and Claridge (2004). However, the climate in their study areas was xeric or drier while the parent materials are much different from the Steese and White Mountains where weather is more humid and warmer.

Soils in Alaska have primarily been studied in areas where resource development, transportation or other infrastructure are planned or located. Activities other than soil surveys have provided access to the sites to allow opportunities for study and sampling. Ping, et al., (2005a, 1998) have focused on soil formation the Alaska Arctic Coastal Plain and the Arctic Foothills but did not venture into the mountain terrain. NRCS soil surveys have covered parts of the White Mountains: Fairbanks NorthStar Borough soil survey and Ft. Wainwright soil surveys lay to the south and west of the Steese Mountains.

The soil catena sequences in Caribou-Poker Creek area (Ping, et al., 2005b) were located to the west of this study area but concentrated on lower elevations of hilly terrain. Other soil studies such as the intense efforts for the Alyeska Pipeline concentrated on engineering properties rather than factors affecting soil formation and were narrowly focused geographically on pipeline corridors which avoided mountain terrain as much as possible. Brown and Kreig (1983) studied the permafrost features along the highway systems from Fairbanks to Prudhoe Bay but did not include the Steese Highway that provides access to this study area. Soil characteristics were described for the soils on the northern coastal plain of the Seward Peninsula in western Alaska (Höefle, et al., 1998) which is at a similar latitude but has a different climate and parent material as well as lacking the mountain terrain.

During an earlier soil survey of the Steese Mountains (Roth, 2012), soil survey crews encountered long term effects of soil temperatures below 0^0C along with permafrost action and other periglacial processes (Slaymaker, 2011). Periglacial processes are defined as a complex of processes involving freezing and thawing including, especially, frost cracking, frost wedging, frost heaving and frost sorting (Washburn, 1973). Thus, periglacial processes affect soil formation in cold climates, regardless of landforms associated with different elevations, and are often associated with areas of permafrost either in the past or at present (Augustinus, 2002; Bockheim, 1990; Ping, et al., 2015).

None of the studies cited above focused on soils of the Steese Mountains in Alaska and have not addressed mountain terrain away from the road system. Each soil profile that was investigated gives detailed information about a specific micro site but is considered representative of a larger area. The micro sites that are present along the elevation transects in the White and Steese Mountains show evidence of being affected by freeze-thaw action (periglacial processes) and to some degree by permafrost (Roth, 2012).

This study is the first to examine how periglacial processes have affected the soil formation and characteristics across a series of toposequences transect in the White and Steese Mountains of central Alaska. The goal of this study is to evaluate the soil characteristics to determine whether there are patterns related to slope position, aspect, parent material, vegetative community and some climatic variables that could explain some of the differences, similarities and potential patterns in the soil profiles of this study area.

This study investigates the influence of elevation, aspect and periglacial (freeze-thaw cycle related) processes on the soils formation in the White and Steese Mountains of Alaska, where permafrost is discontinuous (Péwé, 1975). Jenny (1941) attributed soil formation to five major soil forming factors: parent material, topography, climate, vegetation, and time; but, there may be other factors, such as fire that may account for some of the variation in the White and Steese Mountains soils as one descends from ridge top to valley floor.

THIS PAGE LEFT BLANK INTENTIONLLY

MATERIALS & METHODS

Physiographic setting

Location

The study area is located in the Steese Mountains, which form the eastern part of the White Mountains, located approximately 100 to 160 km east of Fairbanks Alaska (Figure 1). The study sites are all east of Eagle Summit and lay both north and south of the Steese Highway. Access was gained by helicopter in conjunction with the USDA-NRCS Soil Survey.

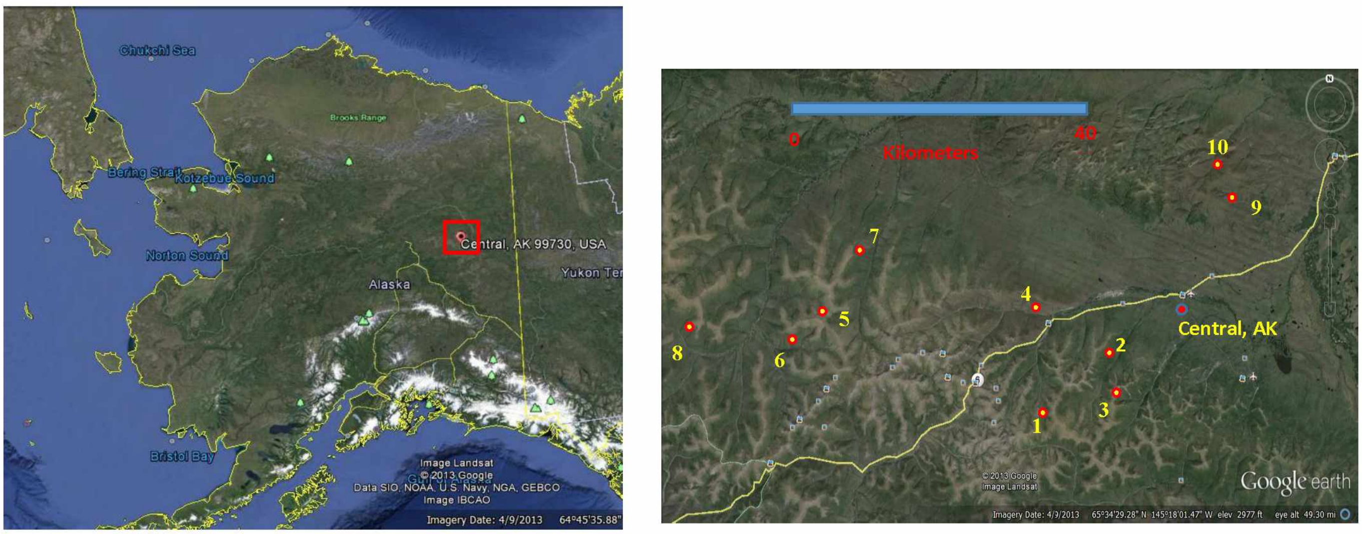


Figure 1. Location of Study Area (L), and Distribution of Transect Locations (R)

Geology and Soil Parent Material

The geology of the Steese Mountains is predominately Late Precambrian Yukon-Tanana metamorphic complex (meta-sedimentary rocks formerly termed the Birch Creek Formation) (Chapman, et al., 1971, Foster, 1992). The parent materials for the soils on the sites in this study are derived from the residuum from schist and from windblown materials (loess) carried in from the Yukon River to the northeast.

At the far northeast corner of the study area the Crazy Mountains are very different geologically from the rest of the White Mountains as they rise above the Yukon River lowlands north of the Tintina Fault and have a very mixed geologic configuration as part of the Tindar Group of sedimentary materials (dolomite, limestone and shale) as well as basalt (Eberlein, 1988).

Glaciation

The area has seen several periods of glaciation that varied in their extent and impact to areas within the study site (Juday, 1988) (Péwé, 1975); however, the area only had limited cirque glaciation during the last ice age which does not appear to have affected the study sites. The unglaciated uplands are typically sculptured largely by creep and solifluction caused by freeze-thaw cycles in the subarctic climate. The abundance of patterned ground, solifluction sheets and lobes, and altiplanation terraces in the study area are results of periglacial processes (Washburn, 1973, Krantz 1990). Broad rounded summits and gentle convex sides of the ridges in the unglaciated uplands are mostly mantled by windborne silt in their lower slope positions (Wahrhaftig, 1965).

Climate

The climate of the study area is characterized by cold dry winters and cool summers with only moderate precipitation (Table 1). Normally for every 100 meters gain in elevation the temperatures drop about 1^0C (Schroeder & Buck, 1970), however, the study area has a complex temperature regime. In the summer the summits are cooler than the valleys while in winter strong temperature inversions often keep the summits warmer than the valleys. Even though there are great daily variations in temperature the mean annual air temperature (MAAT) in the valley is only -5^0C while summits are -6^0C. (NRCS, 2017; US Climate Data, 2017; Fisher2, 017; Weather Base, 2017). The temperature ranges in the study area are well within the ranges noted in the "*Soils of Alaska*" (Ping, et al., 2017b). One of the most important climatic differences within the larger study region is that the lowest elevations (bordering the Yukon Flats) are near or above a ratio of evapotranspiration to precipitation of 1.0 while the higher elevations are well below 1.0 and, thus, sources for the surface flowing waters of the area. The active layer thaw depth reaches its maximum in late summer. Precipitation and wind speeds increase 1.6 and 3 times respectively over the 800-meter elevation gain (Table 1).

Table 1. Location of Meteorological Stations and Climatic Parameters of the Study Area (NRCS, 2017; US Climate Data, 2017; Fisher, 2017; Weather Base, 2017)

Location	Eagle Summit	Central
Latitude, N	65° 29.07’	65° 34.33’
Longitude, W	145° 24.78’	144° 48.10’
Elevation, m asl	1106	295
Mean Annual Precipitation, mm	343	269
Mean High Air Temperature, °C	3	8
Mean Low Air Temperature, °C	-10	-10
Mean annual Air Temp, °C	-6	-5
Wind speed, kph	5 to 60	0 to 20
Period of Record	1998 to 2106	1981 to 2010

Biophysical

According to Viereck (1992) the Steese Mountains lay mostly in the Taiga ecozone biome or boreal forest dominated here by black spruce (Picea mariana (Mill.) Britton, Sterns & Poggenb.) and various mosses. The summits and some of the shoulder areas are described as alpine zone (Ping, et al., 2017b) commonly covered with *Betula nana, Arctostaphylos alpina, Dryas* spp. and other species. The NRCS describes the major land resource area (MLRA) as MLRA-231, Interior Alaska Highlands (NRCS, 2006). In the study of Mount Prindle, located at the western edge of this study area, Juday (1988) described a full range of vegetation from alpine tundra to boreal forest as one descends from the summits to the valley bottoms.

Fire history

The study area has an active recent (decades to centuries) fire history as evidenced by the mosaic of forest stands with different ages and the presence of charcoal in the soil profiles, including various depths in the cryoturbated material. Portions of the study area occur within mapped fire perimeters of 1990, 1991, 2004, 2005, and 2014 (AFS, 2017). Fires in the study area are often landscape scale fires as the area is predominantly in the limited suppression management zone (AFS, 2016), except for the far eastern side near the village of Central, ALASKA. Under a limited suppression management regime most wildfires get little suppression effort. Unburned areas can be found within the mapped fire perimeters, and fire severity often varies considerably across the burn scar, but a fire influence on the ground layer vegetation and upper soil layers is pervasive. Fire plays a major role in the organic layer thickness, drainage patterns and depth to permafrost (Dryness, et al., 1986, Ping, et al., 2017b).

Permafrost and Periglacial Processes

The study area is located within the discontinuous permafrost zone of Alaska and permafrost may extend to 9 meters or more below the ground surface in the Central, Alaska area (Péwé, 1975) (Jorgenson, et al., 2008). Therefore, permafrost may exist below the sampling depth of many of the profiles described in this study even though deep permafrost would not have been a factor in taxonomy of the sites with deep permafrost. Péwé (1975) noted, that although permafrost is more prevalent in fine grained materials, permafrost depth in interior Alaska has not been mapped in detail because of an "almost complete lack of information in the mountainous areas". The data he was able to obtain came mostly from scattered reports of mining operations throughout the area.

Intense frost action occurs within the portion of the soil profile where freeze-thaw cycles occur. Repeated freeze-thaw cycles involve frost heaving which accelerates mechanical weathering of the parent materials. Although permafrost is often wide-spread in areas that display the effects of periglacial processes, it is not required for the process to occur (Washburn, 1973; Péwé, 1975).

In this study soil profiles are grouped to determine where periglacial processes were evident. Then pedon descriptions were compared to determine which periglacial processes are currently active and which are relic features among the various groups of profile data. In areas such as Caribou - Poker Creek and the Steese Mountains, steep southern aspects generally lack permafrost while northern aspects are most likely to have permafrost present due to the differences in solar radiation (Ping, et al., 2017b).

Soil Description and Sampling Plan

Field work conducted in the summer of 2012 was based out of the village of Central, Alaska on the Steese Highway (Hwy 6) with access provided by helicopter. The study sites are all east of Eagle Summit and lay both north and south of the Steese Highway. Field sampling was done in conjunction with the NRCS soil survey of the Steese and White Mountains area east of Fairbanks, Alaska. The project was a third order soil survey at a scale of approximately 1:64,000. The sampling plan for this study utilized a field team of a soil scientist and an ecologist to study several transects with the aim of sampling a range of landform positions and aspects.

Delineation of Transects for Sampling

After selecting the study area, satellite imagery from Landsat 5 was initially analyzed to develop a general picture of the terrain. The best available ortho-imagery and aerial photography were used where possible using “Arc-Map” to determine the land forms and vegetative patterns for the area to create polygons based on the reflectance values of the imagery. Since much of the area has very limited remote sensing data available, some areas were difficult to delineate into polygons (Roth, 2012). Preselection of transect start points was also dependent on having safe helicopter access.

Each day sampling sites were selected from across the study area with the objective of completing a series of soil study sites across an elevation gradient and a variety of landforms to fully describe soils in a variety of ecological settings. It was assumed that variation in vegetative community would be a good indicator of variation in soil composition so vegetation cover type was used as a surrogate for soil types. An effort was made to sample a variety of aspects and vegetation types throughout the study area. Each evening the range of landform positions, aspects and vegetative communities that had been visited to date were reviewed and incorporated into the planning for the next day to ensure a broad representation of the survey area was achieved. Geographic dispersion of sampling provided a broad range of conditions to consider for this study, but the sampling for this study was not designed to be evenly distributed on all aspects or across all landform positions or topographic features because the study area was only a small part of the broader NRCS project. The limited sampling density across the larger soil survey project area did not provide an opportunity to study a confined area. As a result, the analysis of the topo-sequences presented here is a more general discussion rather than a targeted study of a small sharply delineated area. There were 10 transects sampled for laboratory analysis which include a cross section of landform positions and aspects. In the study soil profile samples are labeled with the transect number (1 to 10) followed by the pit profile number (1 to 4). For example, Site 3-2 was the second sample site on Transect 3. The topographic positions were determined in the field at the time of sampling.

Transects

Along each of the ten transects representative sites within ecological communities were carefully selected to avoid edge effects as much as possible. At each soil sampling site, the vegetative community was fully described to determine the ecological site description for that site. The Ecologist/ Botanist provided cover estimates for all species and took samples of unknown species back for identification each evening. As shown in Figure 2 the transects roughly fall into three groups by aspect: north, southeast and west. The southern aspect was reprented by Transects 6 and 8. Transect 8 with a southwest aspect is a mid-slope transect on the contour rather than a topo-sequence so had little elevation change along it. Table 2 presents the locations, shape, slope, and topographic descriptions of the transects.

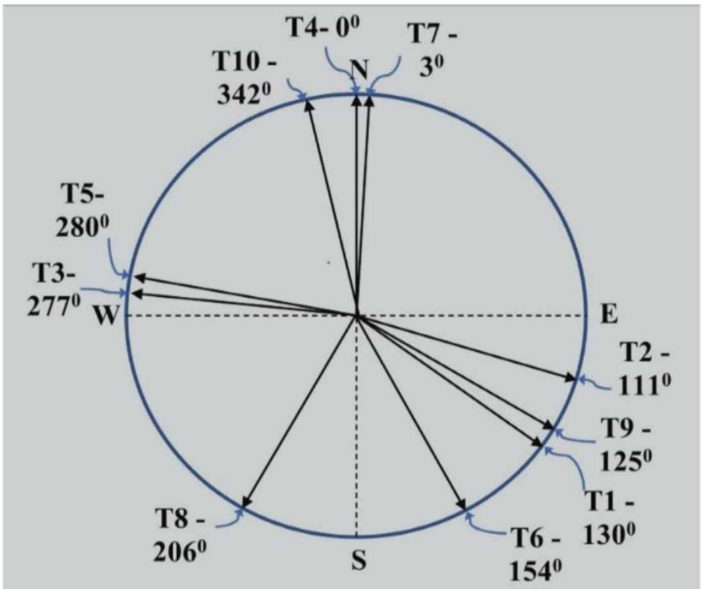


Figure 2. Aspect of Transects

Table 2. Physiography of Transects Selected for Soils Study in Steese Mountain Area, Alaska

Transect #	GPS starting pt. Lat. Long	Starting Point Elevation m	GPS ending pt. Lat. Long.	Ending Point Elevation m	Transects Elevation Range H=m	Horizontal Distance L=m	Orientation of transect (overall aspect)	Transect Average Gradient	Periglacial features	Transect Shape
1	65° 27.22' 145° 13.47'	981	65° 27.37' 145° 12.45'	817	164	842	East	19	Cryoturbation on low shoulder	Convex to Planar
2	65° 31.72' 145° 01.00'	877	65° 31.58' 144° 59.87'	635	242	896	Northeast	27	Sorted circle on summit, Cryoturbation upper slope, Permafrost mid slope	Convex to Planar
3	65° 27.77' 145° 01.22'	1028	65° 27.77' 145° 02.60'	788	240	1057	West	23	Cryoturbation in all Sites, Lichen Stripe in Site 3-3	Convex to Planar
4	65° 34.38' 145° 13.45'	899	65° 35.40' 145 ° 13.18'	666	233	1900	North	12	Cryoturbation on shoulder and backslope	Complex
5	65° 34.35' 145° 48.33'	1022	65° 34.50' 145° 49.87'	892	130	1211	West	11	Cryoturbation in all Sites, Small Solifluction Lobes present	Convex
6	65° 32.12' 145° 54.28'	865	65° 31.50' 145° 53.95'	679	186	2105	Southeast	9	Permafrost throughout, Cryoturbation in lower Sites	Convex
7	65° 39.83' 145° 46.87'	703	65° 40.87' 145° 46.90'	587	116	1913	North	6	Cryoturbation and permafrost in all Sites, Ice wedges at lowest elevation	Planar to Convex
8	65° 33.83' 145° 46.87'	950	65° 33.60' 146° 11.57'	938	12	692	South Southwest	2	Solifluction Lobes and non-sorted circles present across mid-slope of basin	Concave to Convex
9	65° 41.83' 144 ° 37.25'	707	65° 42.00' 144° 35.00'	516	191	1800	East	11	Cryoturbation top and bottom Sites	Convex to Rolling
10	65° 44.25' 144° 42.38'	844	65° 44.67' 144° 42.78'	678	166	829	North	20	Permafrost below ridge, Cryoturbation mid-slope	Convex to Concave

Topographic stratification

Summits

Summits for this project are defined as ridges with the potential for water to flow away from the sample site in three or more orthogonal directions. Often the sites were not at the apex of the ridge but somewhat further down along the spine. The starting elevation for transects that began on ridge tops varied in elevation from 703 m to 1028 m and averaged 920 m. Summit sites are typically exposed to high winds that often leave the summits snow-free during much of the winter. Most ridges were broad and gently sloping with minimal aspect; however, the ridges were not aligned in any particular pattern across the study area allowing multiple aspects to be sampled throughout the project. The parent material was primarily residuum from weathering of schist. Stone pavement and non-sorted circles were common along the summits (Figure 3). Available topographic maps (produced from 1950s era air photos) often indicated summits were non-treed but in this study all sites were nearly covered with lichens and/or dwarf shrubs.

Figure 3. Summits– Summit Position (Site 1-1)

Saddles

For this study the saddles were defined as ridges where water from along the adjacent ridges would flow toward the low point in the saddle from two directions and water could leave the site by a flow pattern that was roughly perpendicular to the incoming water. Saddles were lower in topographic position to the summits described above. Saddles that were sampled were broad, convex and gently sloping with minimal aspect; however, the saddles were somewhat aligned with the ridges and protected to some degree from wind by not having protrusions above the surface. In some storm patterns the saddles may funnel air flow creating a venturi effect. The parent material was primarily residuum mixed with colluvium from weathered schist. The two sampled saddles were at elevations of 902 and 1022 meters. The saddles sampled were covered in lichens and tussocks similar to what might be found on the tundra of the Arctic Foothills (Figure 4).

Figure 4. Saddle Slopes. Tussock Tundra (Site 5-1)

Shoulder Slopes

For this study shoulder slopes can be characterized as sites just off of the summit or saddle but still near enough to the ridge top that slopes were just reaching their maximum convexity. The elevation of sampled shoulder slopes varied in elevation from 703 m to 1028 m and averaged 920 m. Occupying one side of the ridge, shoulder sites were typically sheltered from the strongest winds, allowing for deposition of loess materials in the summer and snow during much of the winter. Shoulder slopes occurred at all aspects and varied from convex to concave in their vertical shape as they wrapped around the nose of a ridge and into the headwaters of the next drainage providing for several sampling opportunities. The parent material was primarily the loess over residuum from schist. Contour lines from the shoulder slopes often wrapped around the summits. Shoulder sites were typically chosen in the field after sampling a summit or saddle position to represent a different ecological community or a change in surface features as the team descended the slope (Figure 5).

Figure 5. Shoulder Slopes, Dwarf Shrubs (Site 1-2)

Back Slopes

Back slopes are the most common feature on the landscape since they include the long slope distances between the summits and foot slopes. They are easily seen on topographic maps as a series of roughly parallel lines. Most sites were slightly convex but could be planar or concave either laterally or down gradient with varying degrees of complexity across the slope. All sites had a unique aspect so that in total several different aspects were sampled. All transects included back slope sites and Transect 8 was entirely made up of sites that approximated a contour of the back slope around a headwater basin. The elevation for sampling sites on the back slopes varied in elevation from 587 m to 950 m and averaged 802 m. The parent material was primarily loess over residuum from schist with colluvium mixed in at several sites. (Figure 6). Except for Transect 8, which was specifically designed to sample only back slopes, the sample sites along the back slopes were chosen in the field to represent the bulk of the ecological and surface conditions that were encountered on each topographic transect. In half of the transects, there was sufficient variability in the back slopes to require multiple sampling sites on the backslopes.

Figure 6. Solifluction Lobes on Back Slopes (Eagle Summit)

Foot Slopes

For this study foot slopes are defined as gently sloping of concave areas near the bottom of the back slopes. In the study area, riparian zones were very narrow and rocky, so foot slopes could extend to the edge of streams. In fact, no riparian zones were sampled for this study due a lack of suitable sampling sites. Foot slopes could be readily seen on topographic maps by the wider spacing of contour lines and were generally shown as being forested. Foot slopes ranged from 3% to 20% with an average of 13%. The elevation for sampling sites on the foot slopes varied in elevation from 516 m to 680 m and averaged 612 m. The combination of position and taller denser vegetation often allows for deposition of materials through aeolian and colluvial transport. The parent material was primarily colluvium mixed with loess material (Figure 7). Most sites were slightly concave but could be planar either laterally or down gradient with varying degrees of complexity across the slope. Foot slopes typically had an aspect nearly perpendicular to the drainage. Due to high variability of the transects higher up the slopes, nearly half of the transects lack representative foot slope sampling sites due to lack of time as dictated by helicopter logistics.

Figure 7. Foot Slope; Mixed Spruce (Site 7-3)

Soil Sampling and Analysis

Soil profiles were exposed by manually excavating a pit and the soil profile description and sampling was in accordance with the USDA-NRCS "Field book for describing and sampling soils" (Schoenberger, et al., 2012). During excavation seasonal frost was frequently encountered; however, the excavation went beyond the seasonal frost to identify the true top of the permafrost. The top of the permafrost was identified by either a desiccated layer between layers with ice and/or a change to more massive ice that is typical of permafrost. Soil classification follows Soil Taxonomy (Soil Survey Staff, 2014), and all terminology according to the Soil Terminology Glossary website: (Soil Science Society of America, 2008). For permafrost affected soils samples for laboratory analysis were collected according to the protocols described by Ping, et al., (2012). Bulk density of organic horizons were measured and cut into blocks then placed into a one-quart sample bag and sealed. Mineral soil samples were estimated to provide 350 g to 400 g air dry weight. Wherever mineral soils had limited rock fragments, bulk density cores of 30 cc were taken as a separate sample. Cores were collected in sealed sample bags for each horizon and stored as a group in a single bag for each profile. Upon returning to the field base the end of each day the samples were placed in a cooler with ice for storage until they could be transported back to the University of Alaska Fairbanks Plant Material and Soils Analytical Laboratory (UAF Lab) at the Palmer Research Center. The samples were stored in a cool room (4^0C) until they were processed for analysis over the following 6 months.

All samples were analyzed in accordance with the standard procedures as specified in the Palmer Research Center Laboratory Manual (Michaelson, et al., 1993), which generally follows the USDA National Soil Survey Laboratory procedures (Soil Survey Laboratory Staff, 1996). The mineral soil bulk density samples were only used to measure bulk density because the samples were oven-dried thus unsuitable for any other analysis. All other samples were analyzed for the following suite of values where appropriate: field moisture content, air-dry and oven-dry weights, loss on ignition (% organic matter), pH, electrical conductivity (E.C.), cation exchange capacity (CEC) by ammonium acetate and microkjedahl digestion, total nitrogen (TN), phosphorus by Mehlich 3 extraction, total carbon (TC) by LECO CNH Analyzer, inorganic carbon by titration, rock fragments (>2mm), iron (Fe) and aluminum (Al) by dithionite-citrate, ammonium oxalate and sodium phosphate extractions, extractable potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na) by ammonium acetate and determined by ICP-MAS. Soil particle size distribution (sand, silt, and clay) was determined by the Bouyoucos Hydrometer method (Day, 1965).

RESULTS and DISCUSSION

Soil profiles were grouped by landform position (see Methods) based on the shape and position on the landscape, elevation and ecological communities. The field investigation and the laboratory results for all sampled soil horizons are presented in Appendix 2. The soil morphological and physical properties of the Steese and White Mountains transects are presented in Appendix 3. The chemical properties are presented in Appendix 4 and the extractable iron and aluminum results are presented in Appendix 5.

Parent materials were also considered when interpreting the profile data. Within the landform positions, the profiles were compared based on their parent materials, genetic horizons, slope, aspect, elevation, and taxonomy. Evidence of periglacial processes and the presence of permafrost were other key components of the analysis. For each landform position the analytical data has been plotted against depth and been aggregated to examine variability by slope position using box plots (Spitzer, Wildenhein, Rappsiber, & Tyers, 2014).

Landform Position

Summits

Exposed soils and rocks in the form of stone pavements and non-sorted circles were common along the summits (Figure 8) similar to what can be observed in the Chugach, Brooks Ranges and other mountainous areas of Alaska. Bockhiem (1990b) observed similar conditions in the Transantarctic Mountains. On three of the four of the summit sites non-sorted circles were observed although very few non-sorted circles were sampled during this study. Summit sites ranged from 20% to 50% surface rock fragments. Common alpine vegetation consisted of 15% to 30% lichen cover with small amounts of *Betula nana, Arctostaphylos alpina, Dryas* spp., and a few other alpine species.

Summit surfaces nearly always appeared to be bare stone pavement. However, removing the stone layer revealed considerable fines below the bare stone layer, so that the overall the rock fragments could be as low as 40% in some instances although values of 65% to 90% were more typical. Lithic and paralithic contact was reached within one meter in 75% of the four summit sample sites. The soil material was mostly generated in-place (residual) from frost action grinding the stones together over time. Summit sites displayed minimal soil development and a depth of one half meter or less. In some instances, the non-sorted circles were interspersed with areas of better soil and more woody vegetation so the pedon would extend up to two meters in width. Drainage on many of summit sites met the criteria of well-drained to excessively well-drained according to USDA-NRCS "Field book for describing and sampling soils" (Schoeneberger, et al., 2012). As a result, evidence of permafrost effects typical of more developed soil profile, such as high ice content or impeded drainage, was usually not present within the first meter of the soil surface. The presence of large surface areas of exposed rock also tends to draw heat into the soils early on summit sites since they are exposed to the wind and thus there is little snow cover to retard surface warming in the brief summer season (Geisler & Ping, 2013). Although early warming allows root development to begin at the start of the summer season, the dry nature of summit sites is not conducive to the growth of vegetation.

Figure 8. Summits– Non-Sorted Circles (Site 2-1), Stone Pavements (Site 4-1)

Saddles

Only two saddles were sampled for this study. Sites ranged from 1% to 20% surface rock fragments and 15% to 85% lichen cover. Saddles tended to be well vegetated often with high water content and gleyed horizons just above the permafrost surface, indicating reducing conditions due to perched water table. Thick organic horizons were common on saddle sites. Cryoturbation sometimes drew organic materials well down into the underlying mineral horizons and well into the permafrost layers in most sites (Figure 9). The thick organic mat provided good insulation against heat penetration in the summer and the winds often blow the saddles free of snow in winter allowing frost to penetrate deeper into the profile. The combination of vegetation and winds provides ideal conditions for retention of permafrost at a shallower depth, i.e. shallow active layers in the sampled sites. The vegetative cover consists of deep moss layer (*Sphagnum spp.* and *Hylocomium splendens*) along with an array of reindeer lichens and dwarf shrubs (*Betula glandulosa, Betula nana, Salix Glauca, Ledum glandulosum, Vaccinium uliginosum, and Vaccinium vitis-idea,*) and ericaceous shrubs. Several species of *Carex* were also present and resulted in the formation of tussocks on saddle sites. Vegetation cover of high elevation saddles contrasts sharply with the lower elevation saddles studied at Caribou-Poker Creek which, supported stands of hardwood trees (Ping, et al., 2005b).

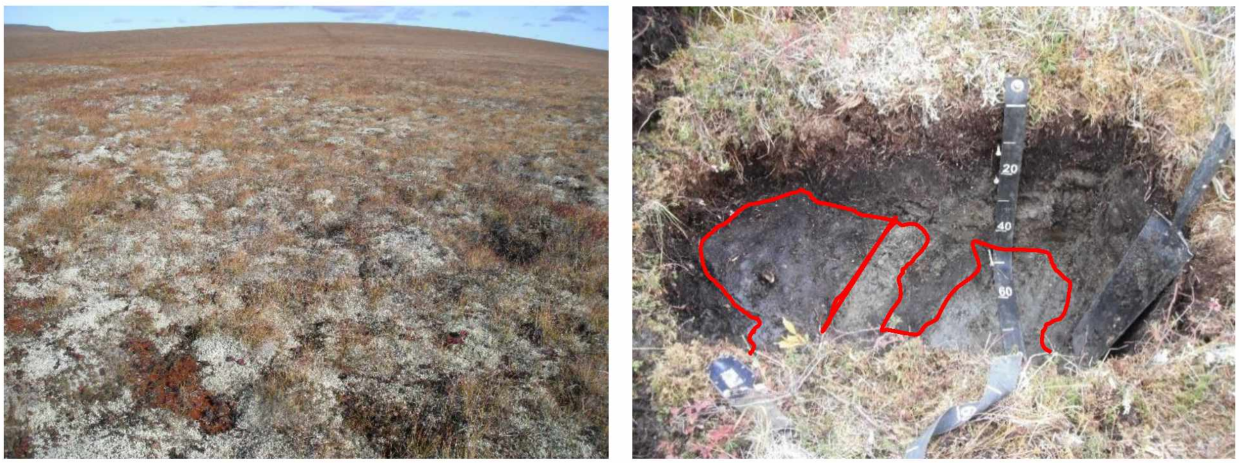


Figure 9. Saddle Slopes. Tussock Tundra (Site 5-1), Cryoturbation (Site 3-2)

Shoulder Slopes

Soils of the shoulder slopes commonly included non-sorted circles and the initial formation of solifluction lobes were common along the shoulder slopes (upper back slopes). Sites seldom had extensive surface rock fragments at the surface and where surface rocks were present it was most often associated with non-sorted circles. The ground surface usually appeared to be fully vegetated except for some exposed non-sorted circles. Typically, woody plants were most abundant on the faces of solifluction lobes where the depth to permafrost was greater than on surfaces between lobes. Downhill faces of solifluction lobes also contained a higher organic content in the upper horizons than the sites between lobes (Figure 10). Shoulder slopes typically supported lichen cover of 5% to 15% while moss cover varied up to 85%. The depth to permafrost was inversely proportional to the thickness of the organic (moss) layer. Active layer depths were one meter or more in areas with dense lichen coverage and only 40 cm to 45 cm under the mossier areas. Other vegetation typical of shoulder slopes included *Betula glandulosa, Betula nana, Vaccinium uliginosum, Vaccinium vitis-idea, Salix Glauca, Empetrum nigrum, and Carex bigelowii* and many other species. This mixed shrub community is in sharp contrast to the forested analogous shoulder slopes at lower elevations as described in the Caribou-Poker Creek watershed (Ping, et al., 2005b).

Upper horizons of soils on shoulder slopes were usually mostly free of rock fragments except for a few sites where the non-sorted circles were present. When non-sorted circles were encountered, the pedon was sampled to extend from the center of the circle out to the non-effected ground adjacent to it. Organic or organic-rich horizons (Oa or A) typically were cryoturbated down into a lower portion of the soil profile and cryoturbation was most evident when the pedon was sampled across the edge or lip of a solifluction lobe or non-sorted circle. In some instances, the cryoturbated material was drawn as far as 95 cm down into the profile (Figure 11).

Figure 10. Cryoturbated Organic Material Outlined in Red – Site 1-3 Shoulder

Drainage on many shoulder slope sites was moderately well to somewhat poorly drained depending primarily on the microrelief, slope of the ground and the depth to permafrost. On shoulder sites a snowpack generally accumulates on the lee side of ridges and persists well into the early summer, particularly on the north aspects. The snow cover insulates the ground to reduce frost penetration in the winter but also inhibits warming of the soils early in the summer particularly on sites with a north aspect.

Figure 11. Shoulder Slopes, Ericaceous Shrubs (Site 1-2), Deep Organic Soils (Site 2-2)

Back Slopes

Back slope sites seldom had extensive surface rock fragments and when they were present they were most often associated with the occurrence of non-sorted circles, stripes or small outcrops of schist. Surfaces were almost fully vegetated except for the occasional exposed non-sorted circle. Large solifluction lobes observed on some back slope sites, but only a few of solifluction lobes were sampled in this study. While remnants of solifluction lobes could readily be found lower on the slope, they rapidly disappeared as the vegetation became taller. Most sites were slightly convex but could be planar or concave either laterally or down gradient with varying degrees of complexity across the slope. Solifluction lobes would often be a source of complex down slope shape, providing a series of benches and drops on what was originally a uniform slope.

Descending down the back slope, the vegetation gradually becomes dominated by white spruce (*Picea glauca* (Moench) Voss) and black spruce (*Picea mariana* (Mill.) Britton, Sterns and

Poggenb.) and a pattern of stripes emerged on the landscape (Figure 12). The mid-slope sites commonly had trees and tall shrubs interspersed with lichen stripes that tended to run down the slope. The lichen covered stripes appear to be elongated non-sorted circles and may be enhanced by the downslope flow of silts in within the exposed soils (Hanson, 1950). Lichen (stone) stripes are interspersed with areas of deep moss that support the woody vegetation. Typically, the woody plants were most prevalent in the inter-stripe areas even though such sites were shallow to permafrost. Reindeer lichen cover ranged up to 95% on the elevated portions of the stripes and a great diversity of species occurred in the inter-stripe areas. Inter-stripe areas commonly support *Picea glauca, Picea mariana, Betula glandulosa, Vaccinium uliginosum, Vaccinium vitis-idea, Empetrum nigrum, Ledum spp., Carex bigelowii, Sphagnum* moss and many other species.

Figure 12. Back Slope, Solifluction Lobes (Eagle Summit), Lichen Stripes (Site 3-3)

The combination of position and vegetation often allows for deposition of materials through wind, water and colluvial transport. The upper horizons of the inter-stripe were usually free of rock fragments while the lichen stripes tended to have medium to large rock fragments of up to 30% to 60% in one or more horizons. It was common for organic or organic-rich material (Oe, Oa, or A) to be cryoturbated to a deeper portion of the soil profile under the lichen stripe. In some instances, the cryoturbated material was churned over a meter down into the profile. Below the organic mat on the inter-stripe there were sites where the upper permafrost contained substantial organic or organic-rich material (Oi or Oe). Drainage on many of the back slope sites met the criteria of somewhat poorly drained to poorly drained, depending on the slope of the ground and the depth to permafrost. In many sites there is substantial evidence of endo-saturation and reduced matrix, as evidenced by the presence of gleyed horizons (Bg and Cg), with redox concentrations along root pores. Mixed redoximorphic conditions may be due in part to water being perched above seasonal frost in the spring prior to the growing season. As the seasonal frost dissipates, the water table slowly recedes and by the time the growing season is underway water is freely draining from the soil profile but the soils remain reduced. As the soil dries out in the summer oxygen permeates down into the profile resulting in ferric iron (Fe^{3+++}) deposits (Figure 13). Tree canopy may provide shade to keep the ground cool, thus slowing the thawing of seasonal frost during the summer.

Back slope soil profiles generally had permafrost present within 40 cm to 60 cm of the soil surface under the organic mat of the inter-stripe and 80 cm to 100 cm under the stripes. Again, the depth to permafrost was inversely proportional to the thickness of the organic (moss) material.

In some of the soil pits on the south facing slopes there was a higher coarse rock fragment content in the profile. Transect 8 roughly followed the contour around an open basin characterized by willow (*Salix*) thickets and sparse spruce. Drainage varied around the basin with permafrost deep below the sampling depth if permafrost was present at all. There were numerous sorted circles and non-sorted circles along the transect and most areas had cobbles, stones and channers within the sampling depths. Transect 6 descended down a steeper slope into a moderate stand of mixed spruce where permafrost was about 80 cm to 100 cm below ground surface. Channers were also present along Transect 6. Transects 6 and 8 showed considerable cryoturbation indicating substantial frost action has been involved in the formation of soils on these transects. Transect 6 has a south easterly aspect with permafrost while Transect 8 did not have any permafrost and was more on a southwesterly aspect.

Figure 13. Back slope; Redox Features (Site 4-2), Rock Fragments and Cryoturbated Organics (Site 8-2)

Foot Slopes

Foot slopes in the Steese Mountains sites had a high content of rock fragments within the profile at varying depths due to colluvial deposition. Rock fragments were less evident in the foot slopes of the Crazy Mountains. A similar difference was seen in the foot slopes of the Caribou-Poker Creek study on the north and south aspects respectively (Ping, et al., 2005b). Foot slope sites were typically near the valley floor with trees and tall shrubs dominating the over-story. Near the bottom of the slopes the vegetation typically became dominated by spruce (*Picea mariana, Picea glauca),* and a scattering of paper birch (*Betula neoalaskana Sarg*.) and quaking aspen (*Populus tremuloides Michx*.). The stripes from the back slopes tended to disappear and *Alnus virdis, Betula glandulosa and Salix glauca* often occupied the mid-canopy position. The soil surface was fully vegetated with *Hylocomium splendens* and other mosses. Typically, the woody plants were evenly distributed across the site. Lichens were more of a minority component of foot slopes. Other vegetation commonly found on foot slopes include *Equisetum arvense, Vaccinium uliginosum, Vaccinium vitis-idea, Empetrum nigrum, Ledum spp., Carex bigelowii*, and many trace species. Tree canopy cover on the foot slope is often dense enough to intercept snow and reduce the end of season depth of snow on the ground. A tree canopy provides shade which slows summer warming of ground and subsequent thawing of seasonal frost.

In 37% of the 35 pedons the active layer was at least one meter deep. Some areas had shallower depth to permafrost previously, with the permafrost surface no longer present within the described pedon but probably present deeper in the profile.

The upper horizons of the profiles had varying amounts of coarse rock fragments but usually only a few (one or two at most) cobbles, stones or channers. Deeper in the profile there was often one or more layers with a higher gravel or coarser rock fragment contents mixed in with the sand and finer soil fractions. In almost every profile on the foot slope there was either a lithic contact or parent material discontinuity from the different fluvial deposits. In 80% of the profiles where permafrost was present there was evidence of cryoturbation of organic matter (Oa and occasionally A) up to 75 cm below the surface (Figure 14). In the non-permafrost affected soils, there tended to be more well-developed A and B horizons than the other sites that were sampled. Drainage on many foot slope sites varied from somewhat poorly drained to poorly drained, depending on the slope of the ground and the depth to permafrost. About one half of the B horizons showed substantial evidence of endo-saturation and reduced matrix with redox concentrations along root pores. Most of the frozen Cg horizons also had a reduced matrix. Mixed redoximorphic conditions may be due in part to water being perched above seasonal frost in the spring and early summer. As the seasonal frost dissipates, the water table slowly recedes and by the time the growing season is underway water is freely draining from the soil profile but the soils in the profile remains reduced. Some foot slope sites were affected by sub-surface drainage that kept the soils nearly saturated (aquic).

Figure 14. Foot Slope; Mixed Spruce (Site 7-3), Cryoturbation of Organic Material (Site 4-4)

Soil Characteristics

Rock Fragments

There are four significantly distinct groups to consider when looking at the rock fragments in the soil profiles: summits, saddles and shoulders, and back slopes combined with foot slopes. Rock fragments are significantly higher on the summits (Figure 15) where wind and water have removed the fine materials that form in the generally thin surface horizons. Loess deposition is limited on summit sites and fines generated from freeze-thaw are rapidly swept away by wind if they are near the surface often resulting in stone pavement on exposed summit surfaces. The sparse vegetative cover and limited buildup of surface organic horizons do not trap and hold fines very well on the summit locations. The summits in the Steese and White Mountains had more exposed mineral soil and coarse rock fragments than the sites in the Caribou-Poker Creek study to the west (Ping, et al., 2005b) where there is thicker loess deposit on the summit position.

Rock fragments were least in the saddle and shoulder position where loess has been deposited in the greatest depth. Thick organic horizons on the saddles and shoulders help trap and hold loess materials and provide substantial insulation thus reducing the amount of freeze-thaw action that might otherwise move rock fragments into the upper portion of the profile. Along the shoulders and back slopes rock fragments increase again due to colluvial movement of material from above. On some sites the overland flow of water may have moved fine soil particles to the lower slopes over time resulting in slightly lower coarse rock fragments on the foot slopes. On the broader plains between the mountain ranges there may be more opportunity for loess deposits at the lower elevations in part due to taller vegetation (rougher surface for wind to cross) that foot slope sites support, which allow for increased capture of airborne materials. The lack of sites in the foot slope strata during this study has not allowed confirmation of the prevalence of deposition; however, more recent observations by the author from continuing soil survey work by the USDA-NRCS in the Steese and White mountains would suggest some support for this hypothesis.

Table 3. Rock Fragments by Slope Position

	Summits	Saddles	Shoulders	Back Slopes	Foot Slopes
Organic Horizons					
Wt Avg %	10	7	5	7	5
Range %	8 to 11	0 to 17	0 to 21	0.0 to 67	1 to 8
Number	16	8	20	51	6
Std Dev	1.63	5.75	6.26	10.57	14.86
Mineral Horizons					
Wt Avg %	17	9	18	46	12
Range %	31 to 94	8 to 10.26	0 to 74	1 to 88	1 to 65
Number	16	3	19.00	56	16
Std Dev	17.29	5.75	21.11	25.82	14.86
Overall					
Wt Avg %	64	8	14	31	17
Range %	8 to 94	0 to 170	0 to 74	0.0 to 88	1 to 65
Number	18	11	39	107	22
Std Dev	25.51	5.75	13.60	25.17	20.86

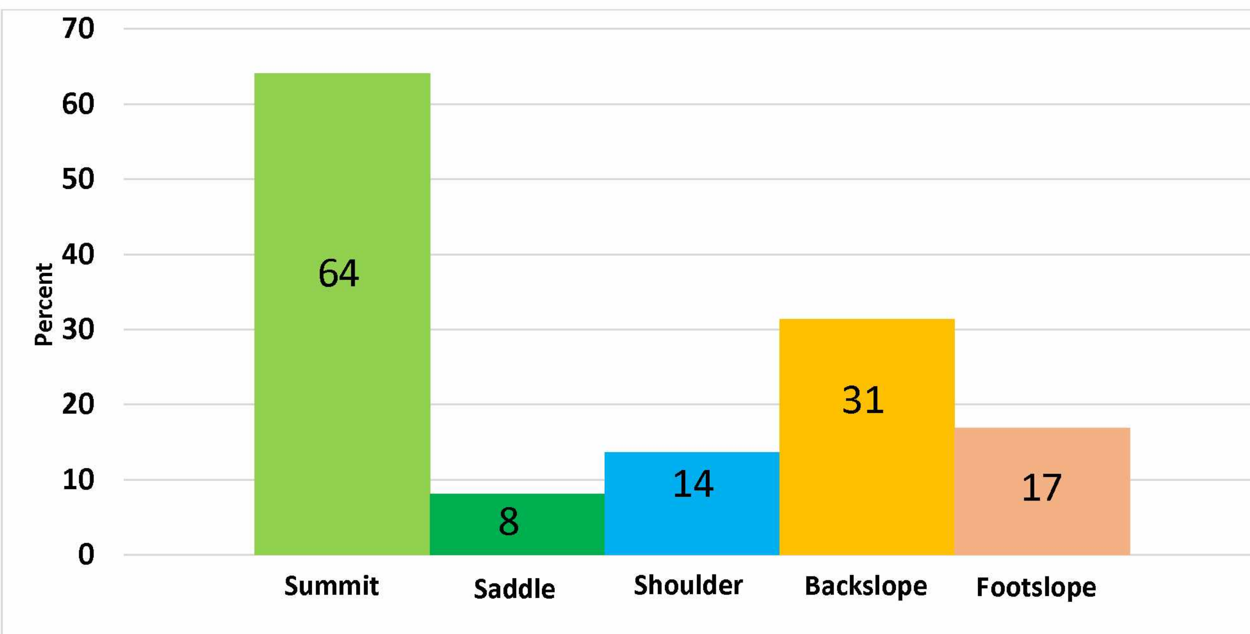


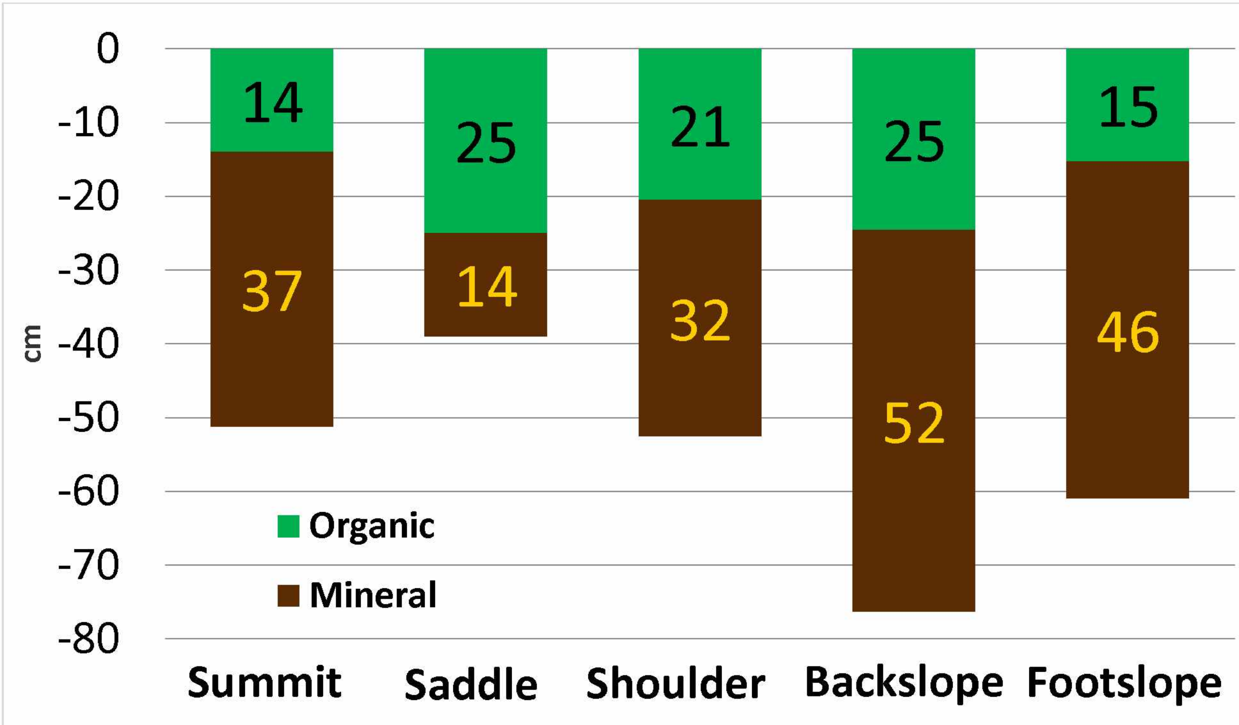
Figure 15. Weighted Average of Rock Fragments Content by Landform

Depths of Organic and Mineral Horizons

Organic horizons were thinnest on the summit (14 cm) and foot slope (15cm) locations (Figure 17), and about one and a half times this depth on the saddle (25 cm), shoulder (21cm) and at back slope (25 cm) positions. The lack of organic material on the summits is related to the harsh environment in which the wind removes snow in the winter, then fine soil particles and moisture in the summer from the sites, which combines to limit the establishment and survival of plants that could contribute to the upper organic horizons. Three of the four sample points on the foot slopes were burned in 2004 or earlier which likely contributed to the shallow organic layers. Overall the organic horizons throughout the study area average 26 cm deep with a range from 4 to 80 cm.

The depth of organic horizons on the saddle, shoulder and backslope are similar; however, there were abundant periglacial features in the form of lichen stripes on the backslope positions that contributed to deeper mineral horizons above the parent material. Lichen stripes are a result of frost action creating non-sorted circles which were then elongated downslope through solifluction creating the lichen stripes. The space between stripes typically supports deep organic soils with a shallow active layer while the lichen stripe has mineral materials very near the surface and a much deeper active layer. A deeper mineral component to the soil pedon results under the lichen portion of the stripes. Lichen stripes are likely an expression of the same processes that form sorted circles on flatter areas near the shoulders and flatter areas (Goldthwait, 1976).

The thinner organic horizons on the footslopes are likely a result of several of the sites having been burned in 2004 or earlier (AFS, 2017) which substantially reduced the original depth of organic horizons. Some sites also had charcoal layers indicating one or more fires at the site.



Notes: Summits OM only represents 1 site of the 4, Mineral depth to the top of the C horizon

Figure 16. Average Thickness Organic and Mineral Horizons on Different Landforms Positions

Soil Reactions in Different Slope Positions.

Soil reaction is expressed by pH that was measured in a 1:1 saturated paste in the laboratory. In general, the pH tends to increase with depth at most slope positions. When classified by slope position (Figures 17 to 21), summits were the most acidic (lowest pH) and uniform with depth while saddles had the most variability with depth. The data on saddle position is based on two sites and may be artificially skewed due to sample size.

Variability of pH is most pronounced in the foot slope profiles followed closely by the back slope sites and least variable on the summits (Table 4). The lower surface pH (weighted average 4.13) is due to the high organic acids released during decomposition of the organic matter (Ping, et al., 2006). The mineral horizons are typically acidic (weighted average pH 4.76) with a pH range of upper four to low five in the mineral horizons for Transects 1 through 8 representing the Steese Mountains. The C horizons had a weighted average of 5.1indicating a continued decline in acidity with depth as the material approaches the parent schist material indicating some weathering is occurring throughout the profile.

The Crazy Mountains in the northeast corner of the study area present a very mixed geological origin for parent material on Transects 9 and 10. The Crazy Mountains profiles have a weighted average pH of 6.09 in 24 mineral horizons; however, the higher pH is most pronounced on Transect 10 where a more calcareous parent material raises the pH to a maximum of 7.73. The more organic surface horizons still present a pH of 5.86 on Crazy Mountain sites illustrating the influence of organic matter on soil chemistry.

The organic acids released from the organic horizons do not seem to penetrate very deeply into the profile as indicated by the trend of increased pH values with depth. The higher pH values at depth may be due in part to limited precipitation and partly to a short growing season which can only produce small amounts of the organic acids to nutrulize bases. The trends and ranges in this study are similar to the trends found in the Caribou-Poker Creek study (Ping, et al., 2005b).

Table 4. Soil pH Comparison by Slope Position and Location

	Summits	Saddles	Shoulders	Back Slopes	Foot Slopes
Organic Horizons					
Wt Avg	4.03	4.37	4.21	4.31	5.30
Range	3.99 to 4.09	3.6 to 5.20	3.47 to 5.47	3.22 to 6.95	4.24 to 6.67
Number	2	8	20	51	6
Std Dev	0.05	0.58	0.52	0.75	1.17
Mineral Horizons					
Wt Avg	4.63	5.10	5.13	4.91	6.81
Range	4.11 to 5.44	4.20 to 5.36	4.17 to 6.69	3.29 to 6.97	4.43 to 7.73
Number	16	3	19	56	16
Std Dev	0.35	0.35	0.63	0.77	0.60
Overall					
Wt Avg	4.55	4.66	4.81	4.66	6.06
Range	3.99 to 5.44	3.6 to 5.36	3.47 to 6.69	3.22 to 6.97	4.24 to 7.73
Number	18	11	39	107	22
Std Dev	0.38	0.62	0.64	0.81	1.14
Steese Mts					
Wt Avg	4.47	4.66	4.81	4.49	4.67
Range	3.99 to 4.96	3.6 to 5.36	3.47 to 6.69	3.22 to 5.80	36.16 to 75.65
Number	15	11	39	90	4.00
Std Dev	0.28	0.62	0.64	0.55	0.30
Crazy Mts					**
Wt Avg	5.31	N/A	N/A	5.87	6.28
Range	4.90 to 5.44	N/A	N/A	4.15 to 6.97	4.24 to 7.73
Number	3	N/A	N/A	17	11
Std Dev	0.22	N/A	N/A	0.99	1.03

N/A = No Samples taken at this slope position
** Note Foot Slope includes pit 7-3 which also had elevated pH.

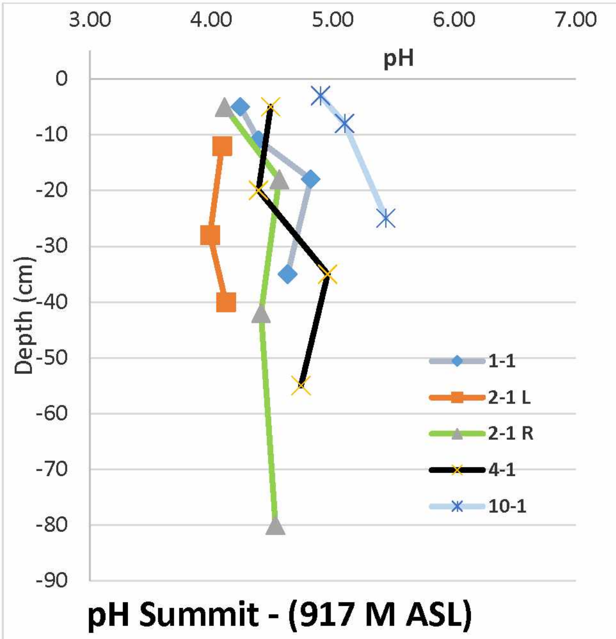


Figure 17. pH of Profiles at Summits

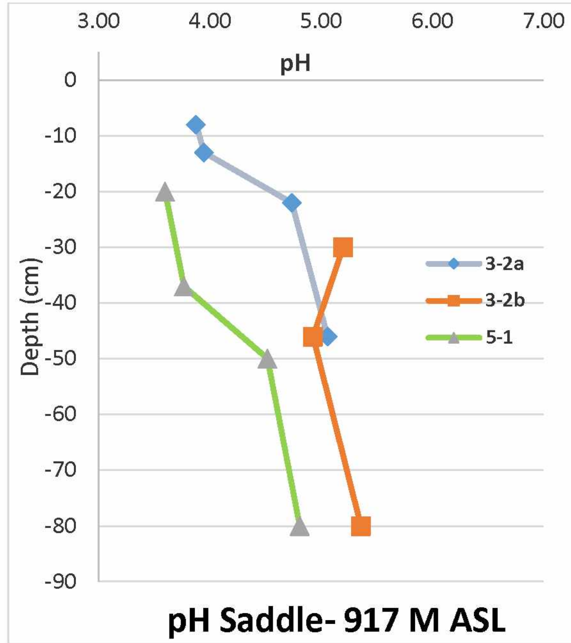


Figure 18. pH of Profiles at Saddles

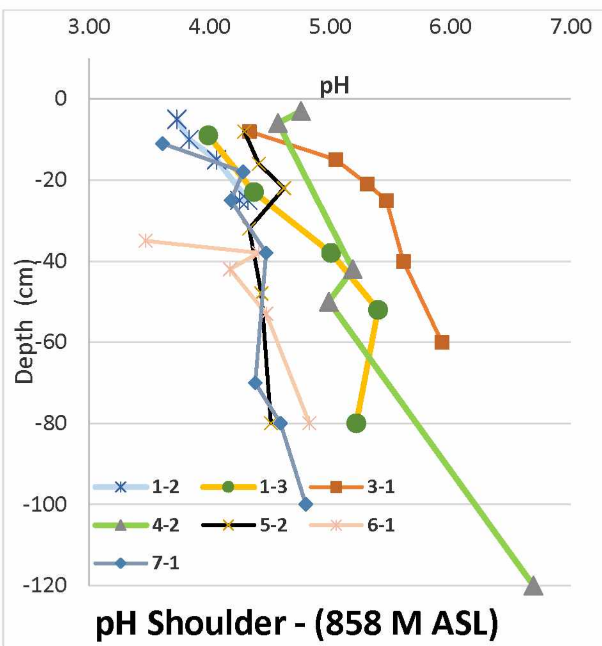


Figure 19. pH of Profiles at Shoulders

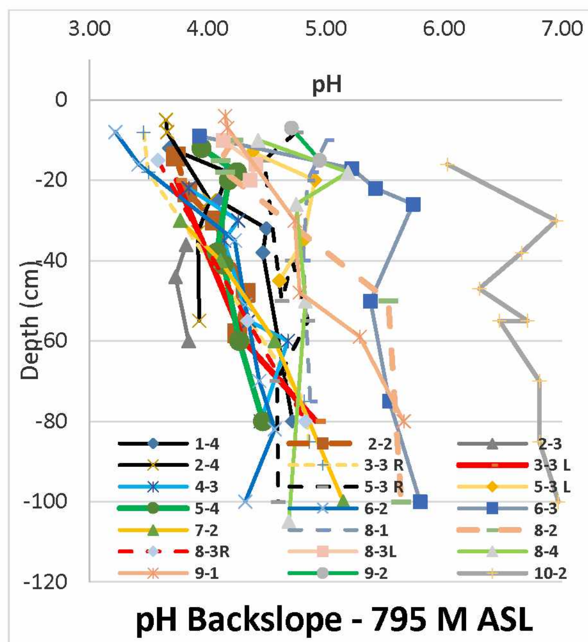


Figure 20. pH of Profiles at Back Slopes

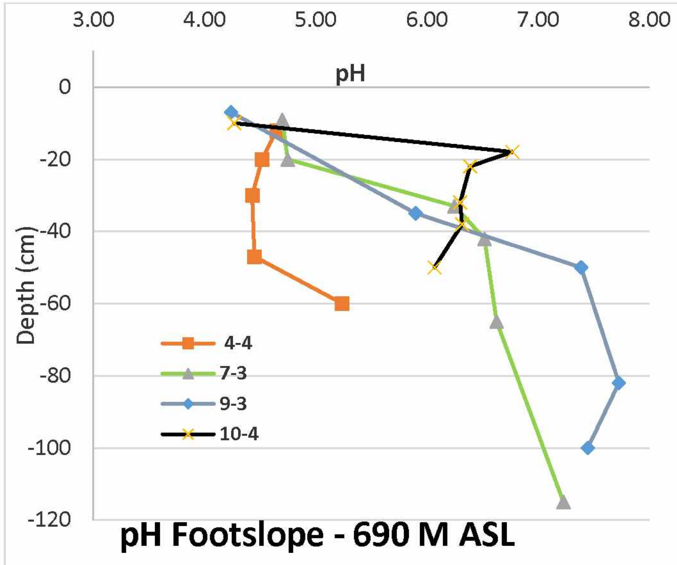


Figure 21. pH of Profiles at Foot Slopes

Soil Organic Carbon Content

At all slope positions, the total carbon content of the organic horizons was substantially higher than that in the first mineral layer (Appendix 4, Figure 22). A carbon content of 10% was used to separate organic horizons from mineral horizons similar to the approach of Michaelson, et al., (2013).

The data indicate that there is minimal translocation of carbon into the mineral soils from the organic horizons immediately above. The carbon content of the summit organic horizons (44%) is only based on one of the four sites as the other summit sites had no organic horizon. Overall the summits lack carbon and organic material. The trend is for increasing carbon content of the organic horizons based on a weighted average of carbon as one descends a transect from the saddles to the foot slopes (32% to 51%). The carbon content of the first mineral horizons across all landforms was 3% to 5% (figure 22) indicating relatively little deposition of carbon into the mineral horizons.

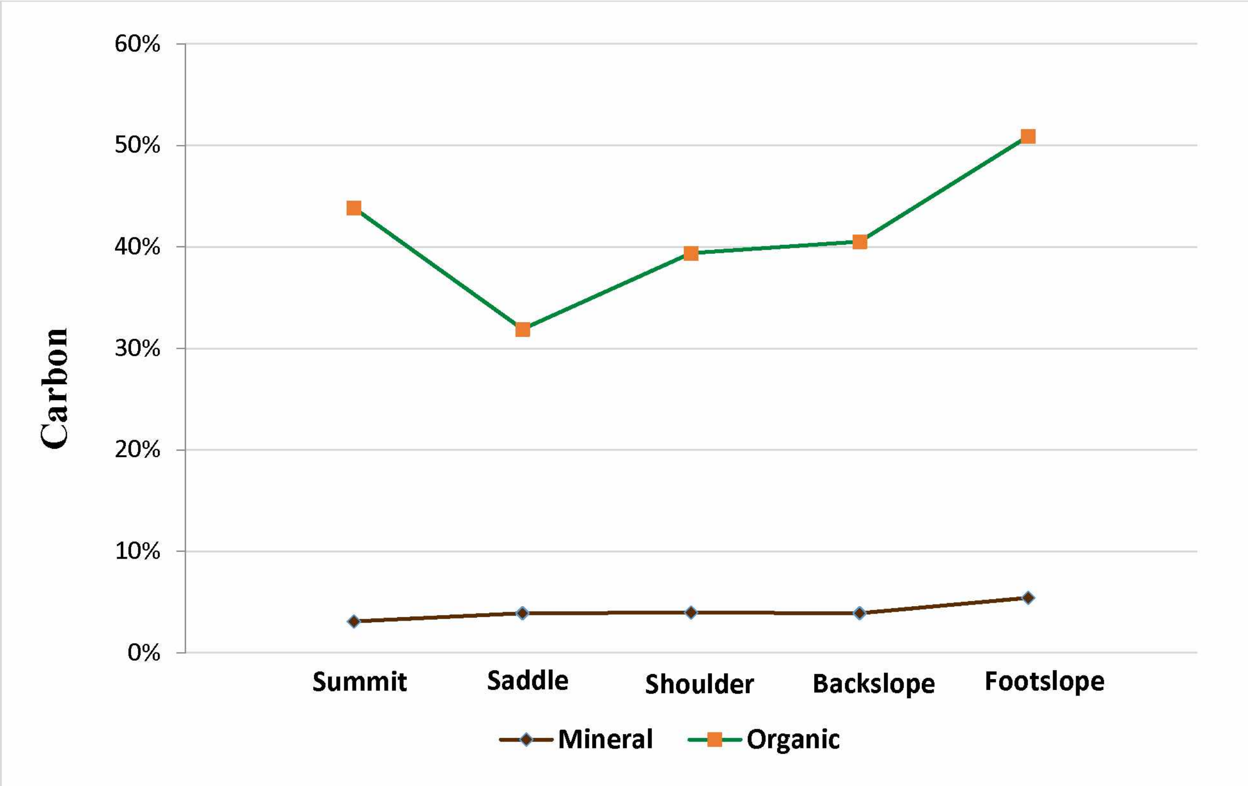


Figure 22. Percent Carbon: Organic Horizons vs First Mineral Horizon

The carbon content of the soil profiles drops rapidly as the organic content of the horizons gives way to mineral materials. In most sites, the carbon content dropped rapidly below the 20 to 25 cm depth. Some carbon was commonly found at greater depths in locations where cryoturbation drew organic materials deeper into the profile (Ajj or Oajj horizons), (Appendix 4). Only at sites 5-2 and 8-1 was the carbon content (13% and 10% respectively) of a non-cryoturbated horizon (Cgf, A) high enough to be considered an organic horizon. The abnormalities from the 35 sites are unexplained at this time.

Nitrogen

In all samples the nitrogen content is less than 3% with an overall weighted average of 0.5% which is somewhat lower that the range noted by Michaelson, et al., (2013). In all slope positions, the higher nitrogen content is closely associated with the organic horizons (Figures 23 to 27). The A horizons have generally 30% to 50% of the nitrogen content of the O horizons and the B horizons have only 5% to 10% of the nitrogen levels in the O horizons. The C horizon nitrogen concentrations were limited to 2% to 4% of the nitrogen found in the organic horizons (Appendix 4). The summit positions are the most nitrogen limited, and this limitation is closely related to a lack of organic materials on three of the four summit sites. Nitrogen levels from the saddle position soil profiles showed the least decline with depth due to the greater depth of organic material.

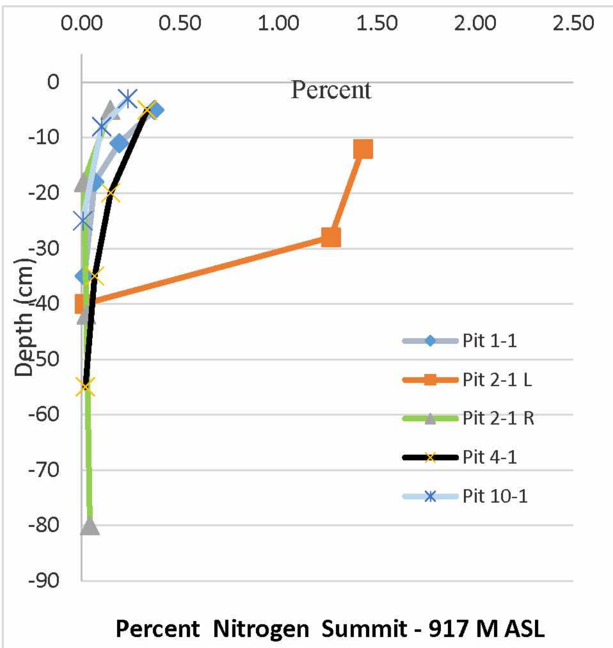


Figure 23. Nitrogen Content at Summits

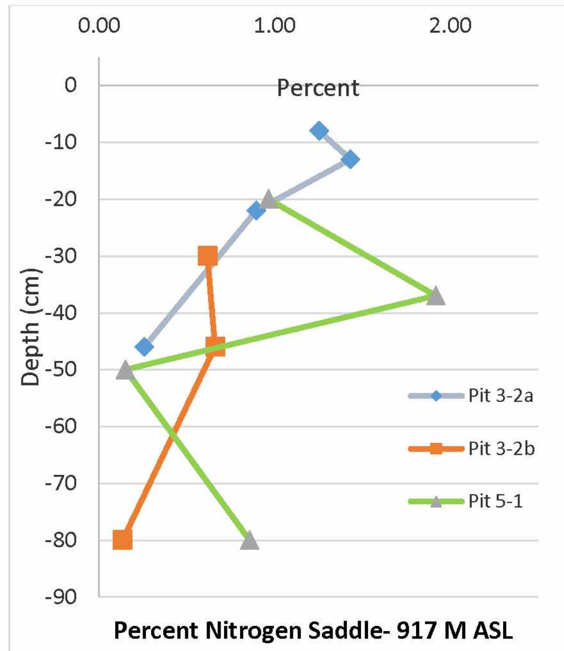


Figure 24. Nitrogen Content at Saddles

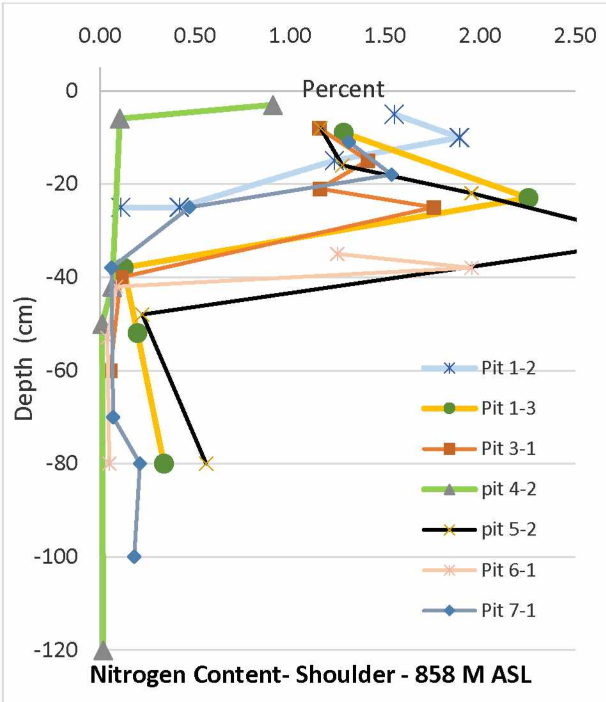


Figure 25. Nitrogen Content at Shoulders

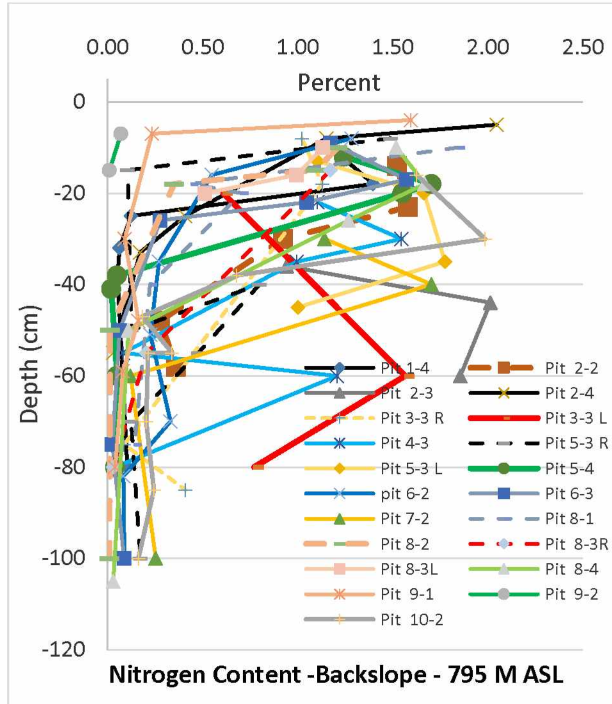


Figure 26. Nitrogen Content at Back Slopes

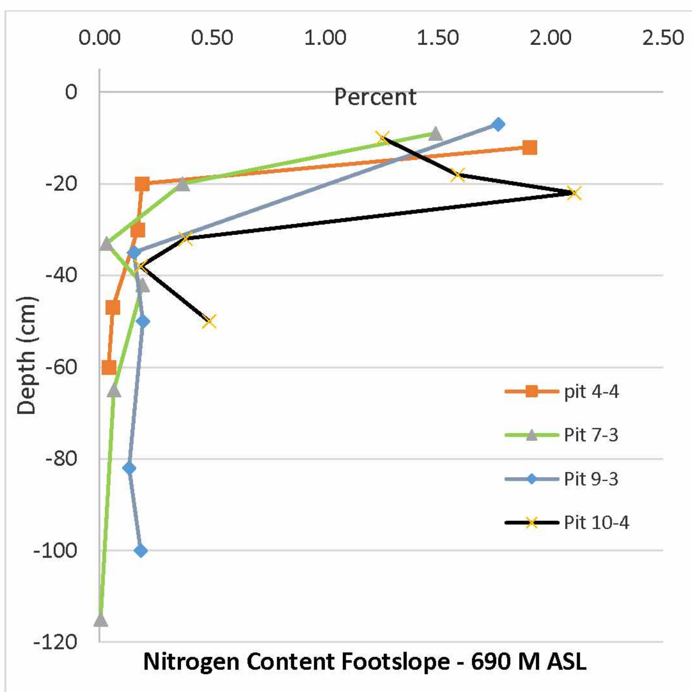


Figure 27. Nitrogen Content at Foot Slopes

C: N Ratio of Organic vs Mineral Horizons

The C: N ratio is often used as an indicator of soil organic matter quality. The more humified soil organic matter (SOM) has a lower ratio than the less humified or fresh SOM. The C: N ratios were about even in the organic horizons for all slope positions although there appears to be a slightly lower ratio in the saddles indicating the organic matter is more humified (Table 5). The C: N ratios on the summits are a little misleading as only one site had an organic surface horizon; however, the first mineral horizon on the summits did have a higher C: N ratio than the mean of the mineral horizons. The higher C: N ratios in the surface horizons is in part due to very low carbon levels and even lower nitrogen levels on the summit sites. Root decomposition may account for the slight elevation of C: N ratios with depth on the summits.

The mean C: N ratio in the mineral soil horizons is consistently lower than in the organic horizons with the saddle and foot slope areas being the lowest. There is a decreasing trend in the C: N ratios in the mineral horizons from the shoulder to the footslope which may be a result of increased decomposition of SOM and possible downward leaching of inorganic nitrogen.

Given the limited number samples represented in this study it is not clear if the C: N ratio differences are significant at this time. In several profiles there is a higher C: N ratio in the lowest sampled horizon (C horizons). In many sites this higher ratio is likely a result of less humified organic matter being cryoturbated deeper into the profile and a very low nitrogen level. On the summit positions and a few other sites higher C: N ratios may be from an accumulation of carbon leached down from above not being able to move into the permafrost or the lithic materials. In some instances, the C: N ratio in the lower horizons were the highest level for the profile (Appendix 4) which appears to be due to either cryoturbation or very low levels of nitrogen (0.01% to .04%).

One shoulder profile (4-2R) had a cryoturbated horizon just above the parent material with very low nitrogen content. The cryoturbated material resulted in a C: N ratio of twice the next highest value (from a surface horizon) and five times the average for the shoulder organic horizons so profile 4-2R was not included in the means in Table 5.

In all instances the weighted mean C: N ratio was higher in the organic horizons than the weighted mean of mineral horizons. High C: N ratios in the organic horizons are attributed to the high content of weakly decomposed organic matter in the organic horizons. In Appendix 4, the organic horizons show from 10 to 50 times the total amount of carbon of the mineral horizons below. The nitrogen levels of the organic horizons are from three to ten-fold the levels in the mineral horizons which helps to account for the narrower difference in C: N ratios seen in Table 5. In most instances the C: N ratios in cryoturbated organic horizons were similar to the mineral horizons adjacent to the cryoturbated materials. The existence of similar C: N ratios in this study is in contrast to the Canadian results where elevated C: N ratio in the cryoturbated materials indicating a slower decomposition of the buried organic material (Hugelius, et al., 2010).

Table 5. Comparison of C: N ratio in Organic and Mineral Horizons in Different Slope Positions

	Summits	Saddles	Shoulders	Back Slopes	Foot Slopes
Organic Horizons					
Wt Avg	33	29	31	33	33
Range	29 to 38	17 to 55	15 to 46	14 to 84	19.28 to 42.53
Number	2	8	20	51	6
Std Dev	4.46	13.09	10.22	12.60	8.39
Mineral Horizons			*		
Wt Avg	26	17	31	21	14
Range	12 to 71	15 to 25	11 to 38	2 to 65	2.5 to 24.33
Number	16	3	18	56	16
Std Dev	17.06	4.58	30.40	10.10	6.33
Overall					
Wt Avg	27	25	30	25	16
Range	12 to 71	15 to 55	11 to 46	2 to 84	2.5 to 42.53
Number	18	11	38	107	22
Std Dev	16	12.85	21.68	12.19	9.30

	Summits	Saddles	Shoulders	Back Slopes	Foot Slopes
Organic Horizons	33	29	31	33	33
1st Mineral Horizon	37	21	25	21	21
Lowest Mineral Horizon	39	22	19	25	18

*** the Bgjj horizon in Pit 4-2R was not included as there was low carbon and almost undetectable nitrogen which resulted in a C: N Ratio of 151, well above the range of other values**

Phosphorus

The highest phosphorus contents were limited to the upper one or two horizons at all slope positions (Figures 28 to32). There appears to be a precipitous loss of phosphorus with depth. In many samples phosphorus in the middle and lower horizons fell to less than one PPM (plotted as 0.05 ppm). The decline in phosphorus with depth is related to the decrease in soil organic matter. Phosphorus is a key nutrient needed for plant growth and is rapidly taken up by plants and very little is leached down into the profile. In a few profiles, there is a slight increase deeper in the profile which is due to the presence of cryoturbated material or the presence of a restrictive layer such as permafrost which allows the accumulation of phosphorus over a long time period.

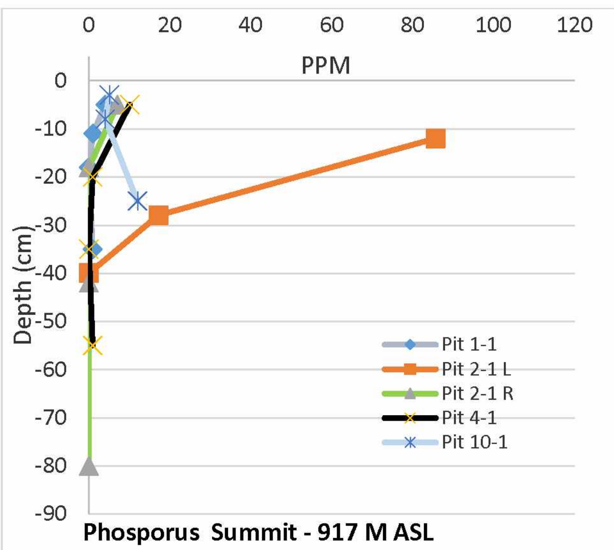


Figure 28. Soil Phosphorus at Summits

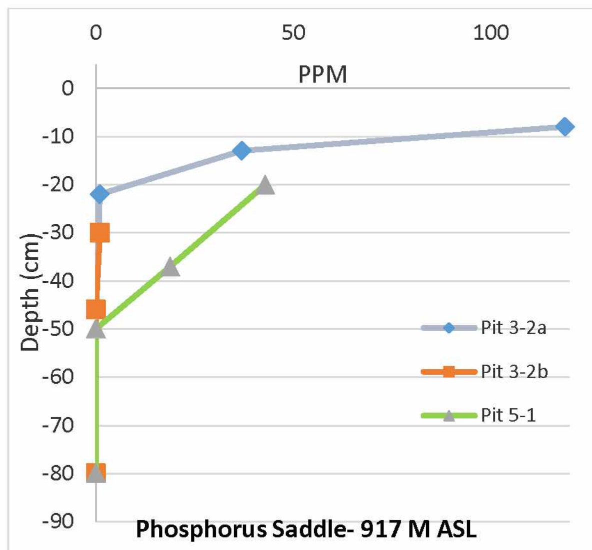
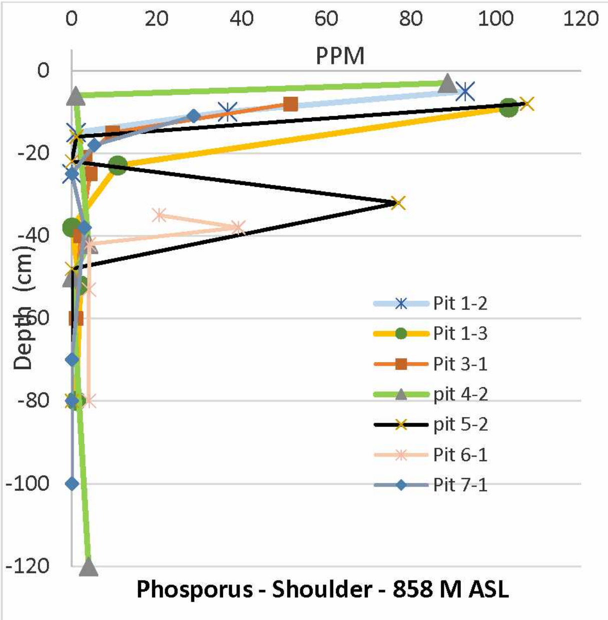


Figure 29. Soil Phosphorus at Saddles



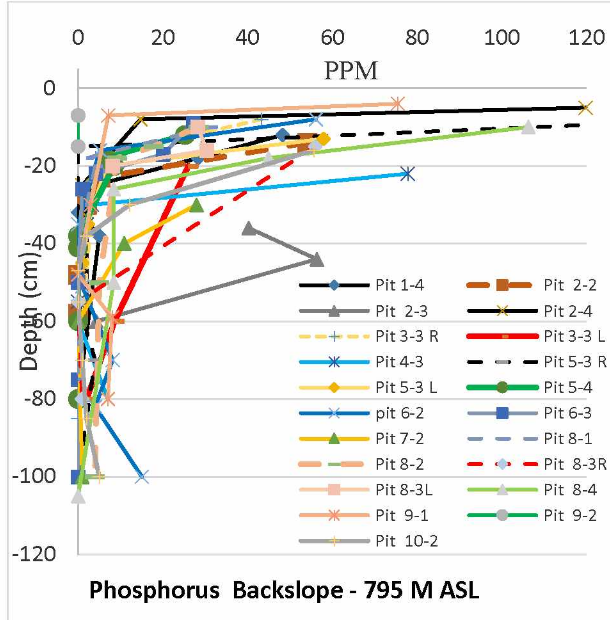


Figure 30. Soil Phosphorus at Shoulders

Figure 31. Soil Phosphorus at Back Slopes

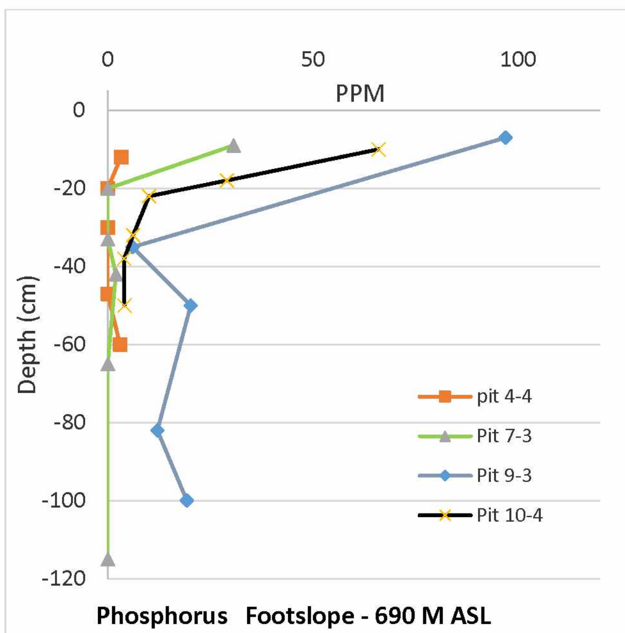


Figure 32. Soil Phosphorus at Foot Slopes

Electrical Conductivity (EC)

Electrical Conductivity (EC) is often used as an indicator of overall soil salinity with larger dS/m values equating to a higher salt content and lower potential productivity. In general EC levels measured in this study are considered to be in the low range and would not be detrimental to productivity. Generally, EC decreases with depth but to a much less pronounced degree than carbon, nitrogen and phosphorus (Figures 33 to 37). At the backslope position there is considerable variability in the rate and regularity of the decline. On the shoulders there is a moderate increase in EC from mid-profile to the bottom of the sampling depth. On the footslope Site 9-3 shows more than a ten-fold increase in EC with depth. The rising EC values below 50 cm corresponds with the increased pH values (>7.5) is due to accumulation of soluble salts as indicated by the presence of inorganic carbon and high extractable calcium. Higher EC at site 9-3 is likely related to the unique geologic parent material in this area of the Crazy Mountains. Site 9-3 was also the only birch forest site sampled on this study so there are no similar sites for comparison. The summit and saddle positions show a general decline with depth but at a very much less pronounced rate than the other nutrients.

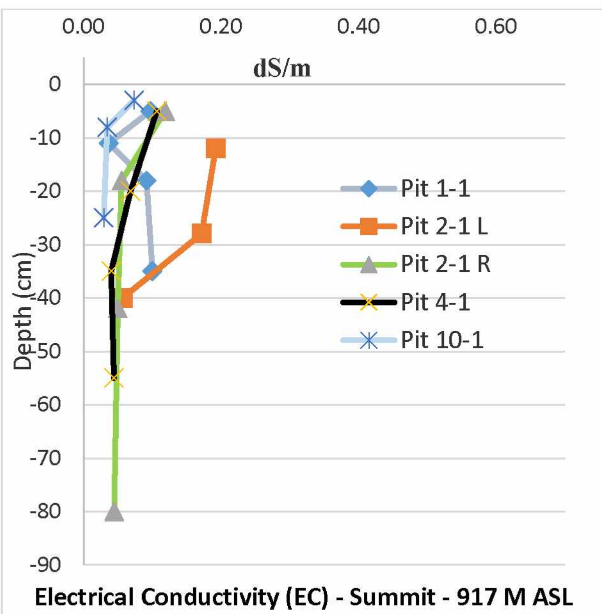


Figure 33. EC at Summits

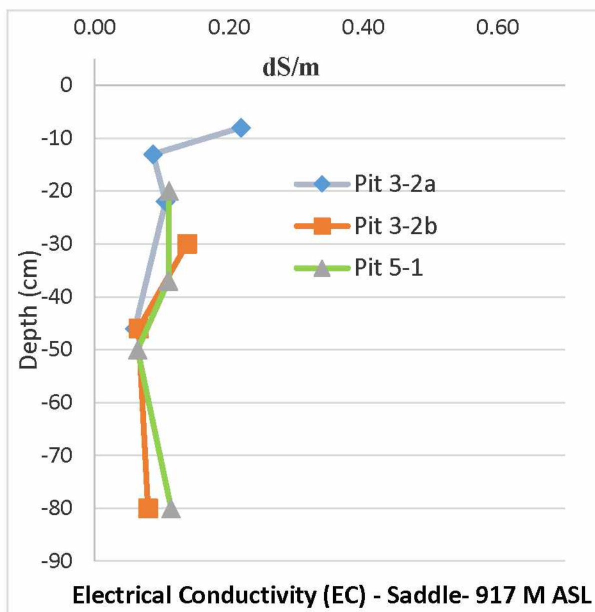
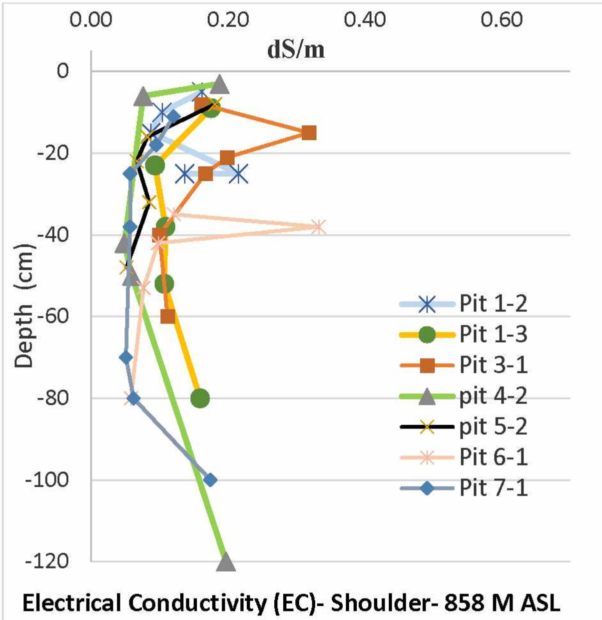


Figure 34. EC at Saddles



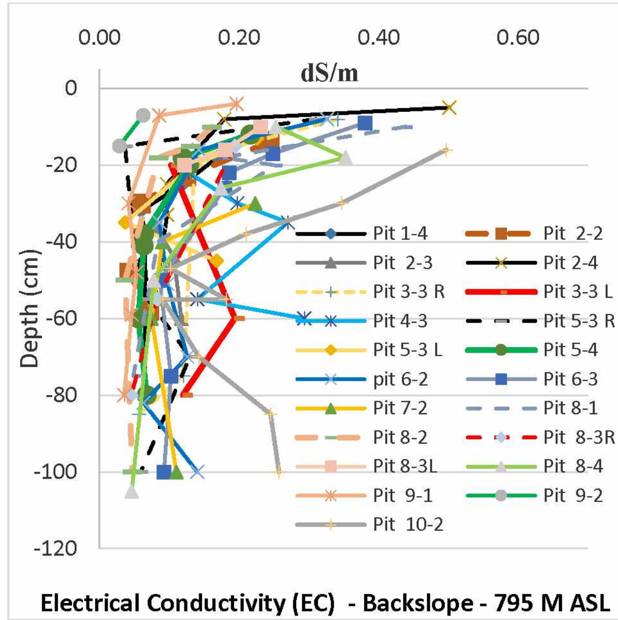


Figure 35. EC at Shoulders

Figure 36. EC at Back Slopes

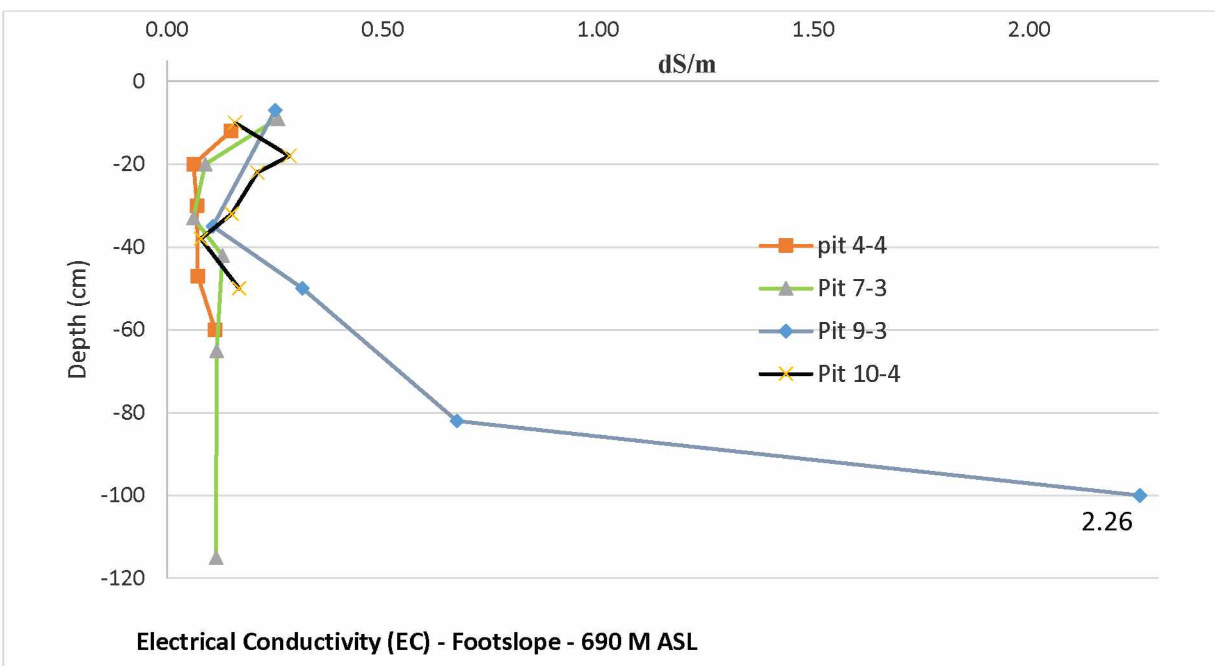


Figure 37. EC at Foot Slopes

Cation Exchange Capacity (CEC)

Cation Exchange Capacity (CEC) measures the ability of the soil to retain base nutrients and is a measure of soil fertility. Since there are limited amounts of clay in the soils of the study area the CEC is more closely related to the organic content than the clay content (Ping, et al., 2005) (AgSource, 2014). There is a general trend of CEC decreasing with depth but the decrease is much more gradual than any of the other changes analyzed above (Figures 38 to 42). The magnitude of change between adjacent horizons and between organic and mineral horizons does not show as sudden or precipitous a change for CEC as it does for other analytes. The organic horizons show a range of 22 to 177 cmols^{+}kg^{-1} with an average of 75 cmols^{+}kg^{-1} while mineral horizons range from 0.3 to 49 cmols+ kg-1 with an average of 13 cmols^{+}kg^{-1} (Table 6). While there is considerable overlap there is a usually a clear step down from the organic to the mineral horizons within any given site (Appendix 4). The ranges of CEC in this study are generally lower than the CEC observed on most soils in the boreal and arctic regions of Alaska (Ping, et al., 2005a; 2005b; 2017a) because of the lower organic carbon contents in alpine soils of the study area.

Table 6. Cation Exchange Capacity Comparison by Slope Position

	Summits	Saddles	Shoulders	Back Slopes	Foot Slopes
Organic Horizons					
Wt Avg cmols+ kg-1	67.21	58.81	73.49	74.32	102.50
Range cmols+ kg-1	62.37 to 70.85	32.27 to 113.43	29.02 to 102.58	22.51 to 154.24	73.04 to 177.03
Number	2	8	20	51	6
Std Dev	4.24	24.11	18.41	27.01	40.62
Mineral Horizons					
Wt Avg cmols+ kg-1	7.69	12.35	14.81	12.61	19.27
Range cmols+ kg-1	0.33 to 18.64	9.15 to 18.37	7.23 to 33.28	4.67 to 34.36	6.24 to 49.08
Number	16	3	19	56	16
Std Dev	4.36	4.31	4.35	6.73	12.33
Overall					
Wt Avg cmols+ kg-1	14.78	40.88	33.45	35.06	28.66
Range cmols+ kg-1	0.33 to 70.85	9.15 to 113.43	7.23 to 102.58	4.67 to 154.24	6.24 to 117.03
Number	18	11	39	107	22
Std Dev	18.55	32.44	32.21	35.48	42.82

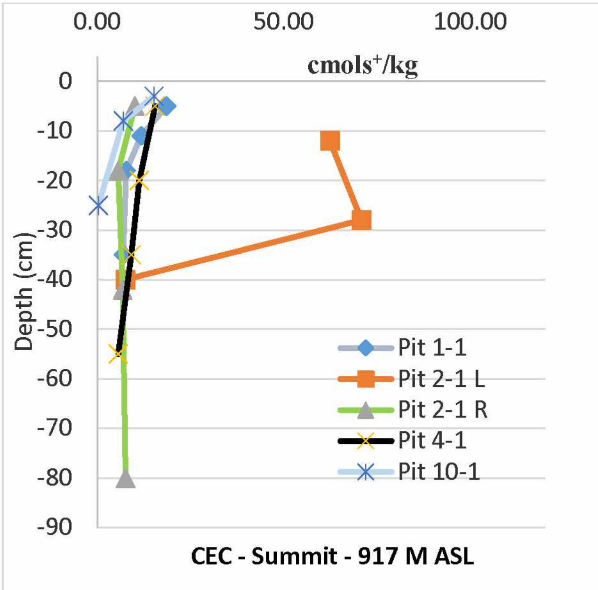


Figure 38. CEC Values for Summits

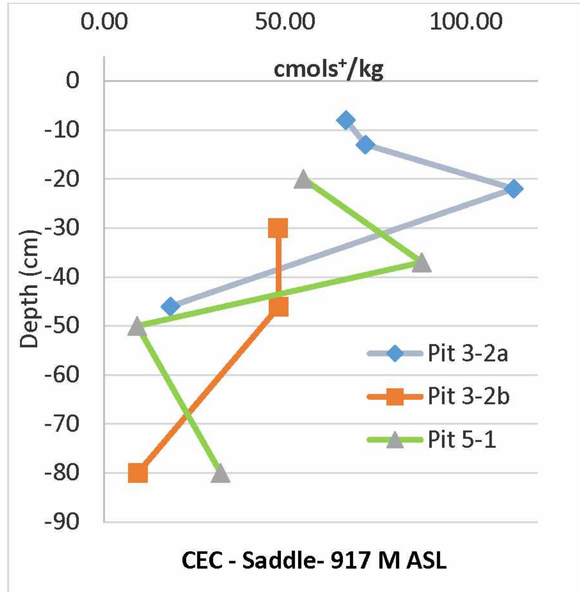


Figure 39. CEC Values for Saddles

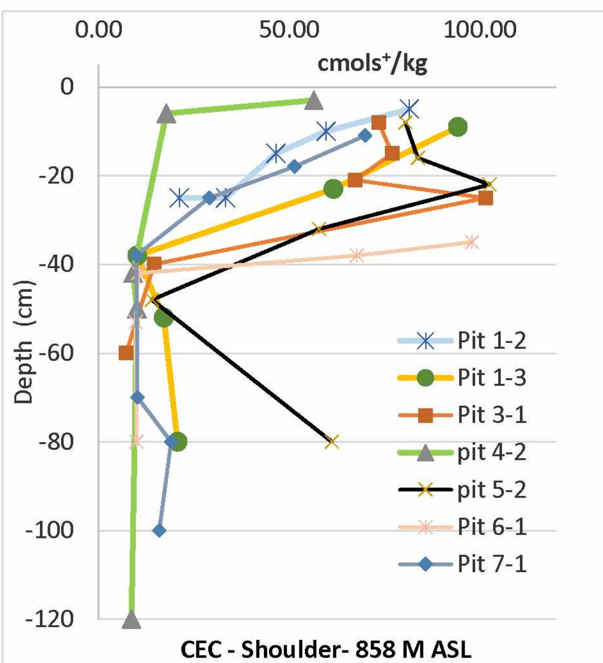


Figure 40. CEC Values for Shoulders

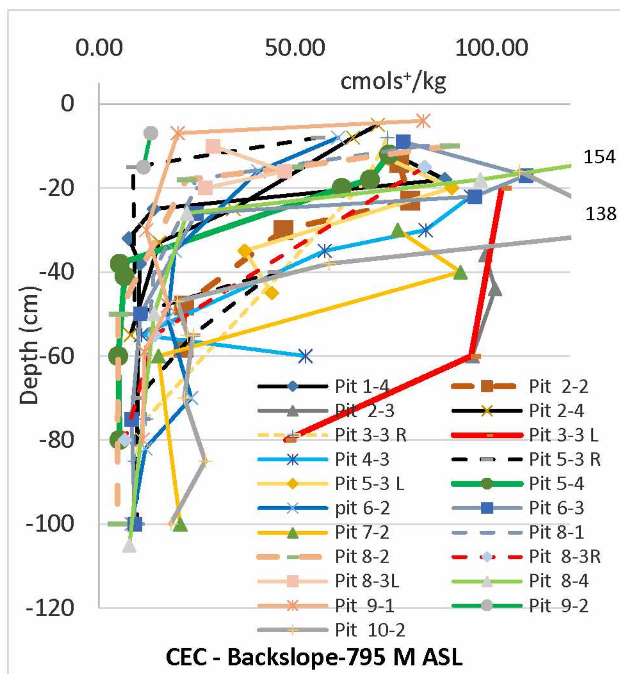


Figure 41. CEC Values for Back Slopes

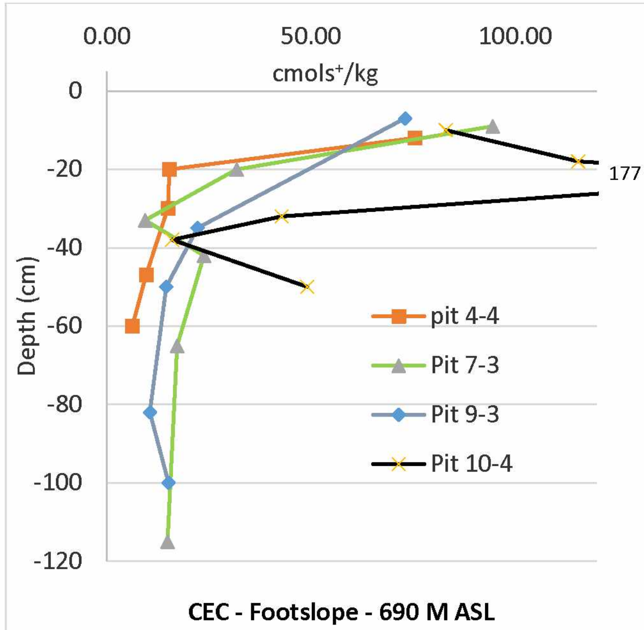


Figure 42. CEC Values for Foot Slopes

Base Saturation

Base saturation is a measure of the extractable cations relative to the cation exchange capacity. When the base saturation reaches 100% the exchange sites are fully occupied and cations are readily available for plant uptake (Sonon, et al., 2014). In the summit profiles the base saturation averaged only 16% while the saddles, shoulders and back slopes were between 45% and 47% (Figure 43). The foot slope sites were concentrated in the Crazy Mountain where the parent material is calcareous, thus the average base saturation rose to 100%. In three quarters of the profiles for the foot slopes, the base saturation was over 50% for the upper 25 cm of the mineral soil. Overall, 24% of the soil profiles had a base saturation of over 50% for the upper 25 cm of the mineral soil (Appendix 4). Generally, the base saturation tends to be low in acidic soils due to increased leaching loss.

In figures 43 and 44 the boxes represent the inter quartile range (IQR) from the 25th to the 75th percentile. The line in the box is the mean and "X" represents the median value. The bar at the ends for the solid lines represent values that are within 1.5 times the IQR both above and below the IQR.

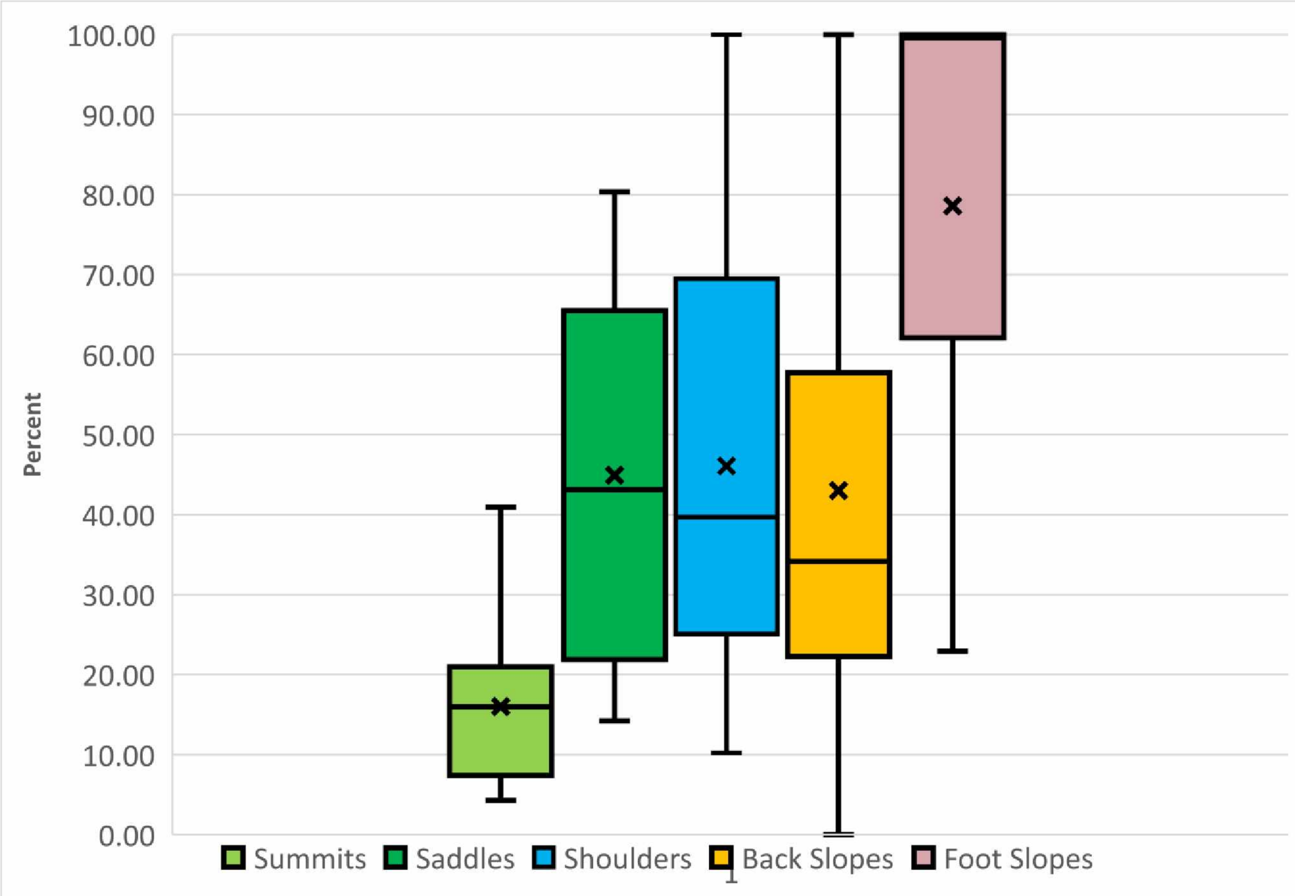
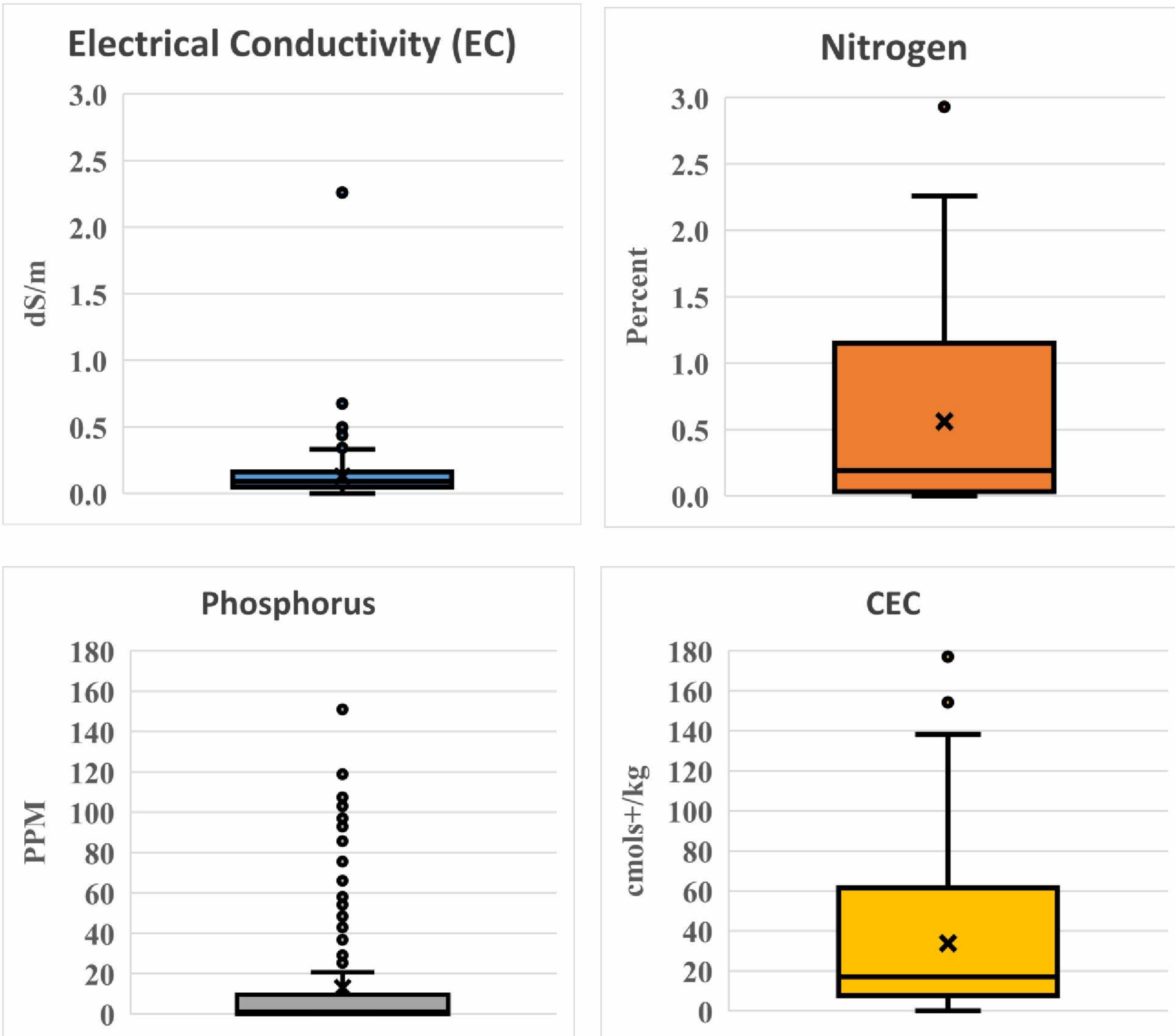


Figure 43. Range of Variability of Base Saturation

Soil Nutrient Status

The variability of select nutrients are compared in figure 44. Phosphorus has the most values outside the inter quartile range of variability while both CEC and nitrogen had the fewest outlying values. The box plots show that within the range of variability EC and phosphorus had the tightest grouping of values within the inter quartile range. Nitrogen and CEC are similar in their spread of values and variability. However, phosphorus and CEC values are a factor of 60 larger than the range of values for EC and nitrogen. Outlaying values for phosphorus were almost exclusively associated with the uppermost organic horizons at all slope positions on most of the sample points. Because of the high phosphorus content of the O horizons, the mean value (X) is just above the inter quartile range of values represented by the colored box on the plots.



Dots beyond the lines represent outlier values (Spitzer, et al., 2014).

Figure 44. Range of Variability for Various Soil Properties

Iron and Aluminum

Dithionite-citrate extractable iron (Fed) gives an indication of the free iron in the soil (Parfitt & Childs, 1988, Ping, et al., 1989). Free iron is iron adsorbed to soil particles and when compared with amorphous iron gives an indication of weathering. A similar pattern is seen with the free and the complexed iron and aluminum; however, the free iron shows higher values and larger variance in the deeper horizons than the extractable aluminum. Some of the higher free iron is due to cryoturbation but some is also showing in the B Horizons and at the permafrost interface indicating that free iron is being leached down through the profile to a small degree. Iron (Fe) and

Aluminum (Al) extraction by sodium-pyrophosphate (Fep, Alp) are an indication of how much of these elements are complexed with organic material (Parfitt & Childs, 1988, Ping, et al., 1989). Profiles on all landform positions generally show a decrease in values with depth but there are several profiles where the horizons deepest in the profile are at or above the values higher in the profile for either Al or Fe or both (Appendix 5). Higher iron or aluminum low in the profile is indicative of humus being complexed in materials that have been cryoturbated deeper into the profile. Both Alp and Alo vary within a narrow range generally less than 0.4 indicating a low degree of mineral weathering. The Fed is generally between 0.2% and 2.0% which indicates minimal weathering however 6% of the horizons were between 2.0% and 8.5% indicating that stronger weathering has occurred in at least one site on all land forms except the summits. The minimal variation with depth is in contrast to the results Ping, et al., (1989) found in the volcanic soils of southern Alaska where weathering was closely tied to the age of volcanic deposits.

Permafrost

Permafrost was present in 20 of the 35 soil pits (58%) at an average depth of 79 cm. The only transect without permafrost was Transect 8 which was a mid-slope transect in a south-facing basin with a high coarse rock fragment content ranging from cobbles to channers in size. Areas with large coarse rock fragments likely conduct heat well down into the soil. The presence of sorted circles and non-sorted circles along this transect (Figure 45) indicate considerable frost action does occur throughout the basin but is apparently not currently driven by permafrost but can be rather a common phenomenon in the periglacial environment (Washburn, 1973). There may have been permafrost at sites with high coarse rock fragments previously, or still, but the depth to permafrost is well below the sampling depth of 100 cm on this south facing site.

The transects were grouped into four aspect groups with three in the southeast aspect, two southerly, two westerly and three near north. Approximately 50% to 75% of the sites along each of the transects (except Transect 8) had permafrost present within the sampling depth. Where profiles did not hit permafrost they often reached lithic contact or parent material before they reached 2 meters in depth so the presence of permafrost was not conclusively ruled out in some sites. When all the transects within each aspect group are included, the percentage of soil profiles with permafrost range from 50% to 60%. The western aspect soil profiles have 86% with permafrost which would be a distinct difference from the other aspects. By including the two footslope profiles (sites 4-4 and 7-3) in the burned areas that exhibited evidence of previous permafrost presence, the north aspect would exhibit 80% of the profiles with permafrost which would also be distinctly different.

Figure 45. Non-Sorted Circles - Transect 8

The average depth of the active layer across all aspects ranged from 59 cm to 62 cm for the sites with permafrost. Aspect did not have any effect on the average depth of the active layer based on the sample sites in this study.

When comparing the various soil profiles by landform position, the permafrost was found in 25% of the summit profiles, 100% of saddle profiles, 67% of the shoulder slope profiles, 57% of the back slope profiles (75% when excluding Transect 8 due to the high incidence of coarse rock fragments) and 50% of the foot slope profiles. Foot slope sites 4-4 and 7-3 appeared to have been influenced by permafrost before fire which would raise the foot slopes to 100% influenced by permafrost. The depth to permafrost ranged from 30 cm to 82 cm at individual study sites; however, when comparing sites by topographic position the weighted average range was only 55 cm to 66 cm. There was no significant difference in average depth to permafrost based on slope position. In sites where permafrost was not found within the sampling depth it is likely that sites with high coarse rock fragments or lithic contact did not have permafrost within 2 meters of the surface. On sites where parent material was encountered without permafrost it may be possible that permafrost is within 2 meters of the surface and there is just a very deep active layer.

In sites 4-4 and 7-3 permafrost was not found but there was clear evidence of cryoturbation. Both of these sites showed evidence of wildfire with Site 4-4 having fire on the site only eight years before sampling. The gentle slope of these sites may have contributed to more solar input than might otherwise be expected on a north aspect transect. Fire in the boreal regions repeatedly played a role in deepening the active layer due to the loss of insulation from the removal of surface organic layers immediately following fire events (Dryness, et al., 1986, Mackay, 1995). The vegetative recovery at Site 7-3 may reverse the trend of loss of permafrost after fire in the near future with black spruce providing shade cover to the site and allowing permafrost table to rise as seen in the Inuvik study in the northern boreal forest of Northwest Territory Canada (Mackay, 1995).

While permafrost may not have been present on all the sample sites within the sampling depths, this does not mean permafrost is totally absent from any sites within the study area. It only means permafrost was not captured in the sampling depths. For soils without cryoturbation, soil taxonomy requires evaluation to a depth of 2 meters for soils to be classified into the Gelisols order (Soil Survey Staff, 2014) and that depth was never reached on the sites in this study. In 1975 the approximation of permafrost thickness just east of the study area along the Yukon River near Circle, Alaska was estimated to be 9 meters from limited data gathered from mining operations by Péwé (1975). Deep permafrost may help rebuild frozen conditions toward the surface as epigenetic processes draw frost toward freezing fronts at the top of the permafrost and the ground surface. As the two fronts freezing continue to form, the active layer may decrease as the permafrost table rises into the soil profiles (French & Shur, 2010). As in the case of Site 4-4 and 7-3, permafrost might retreat below 2 meters after the fire, but permafrost could rise again to the pre-burn level after reestablishment of vegetative cover that could insulate and cool the soils (Ping, et al., 2017b; Viereck, 1983; Viereck, et al., 1993).

Analysis of Periglacial Processes across the Toposequence

Freeze-thaw cycles have contributed considerably to soil formation at many of the sites across the study area. Frost has sorted materials into sorted and non-sorted circles (Figure 46) and stripes (Figure 47) which can be readily seen as surficial features. In the process mineral material and rock fragments were moved up to the surface by frost heave through repeated freeze-thaw cycles. The result of coarse rock fragments being pushed to the surface is an increase in the absorption of heat into the soil surface and the conduction of heat deeper in the soil profile. On some sites, freeze-thaw cycles lead to incorporation of organic materials deeper into the profile through cryoturbation (Figure 48). Frost action has also developed cracks in the soils that are readily visible in summer in some locations (Figure 49). These cracks fill with soil and water during the summer and can lead to the formation of ice wedges similar to those seen in polygonal ground patterns on the Arctic coastal plain and in the permafrost tunnel in Fox, Alaska.

Figure 46. Non-Sorted Circle – Site 2-1

Figure 47. Lichen Stripes – A Form of Non-Sorted Circle

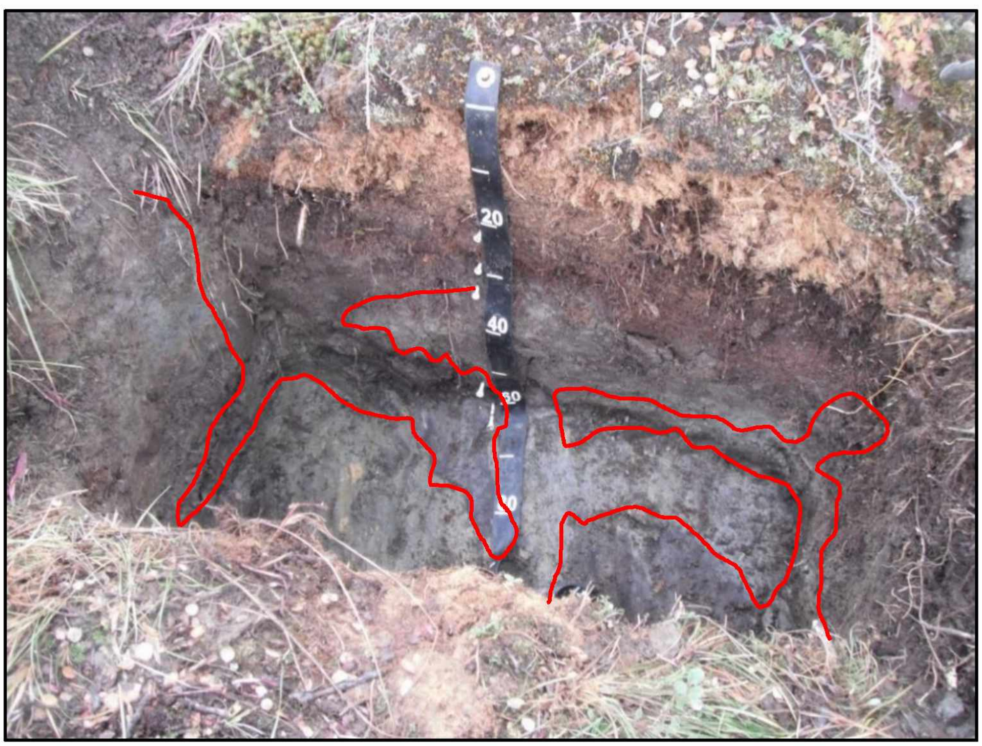


Figure 48. Cryoturbated Organic Material Outlined in Red – Site 4-3 Burned Site

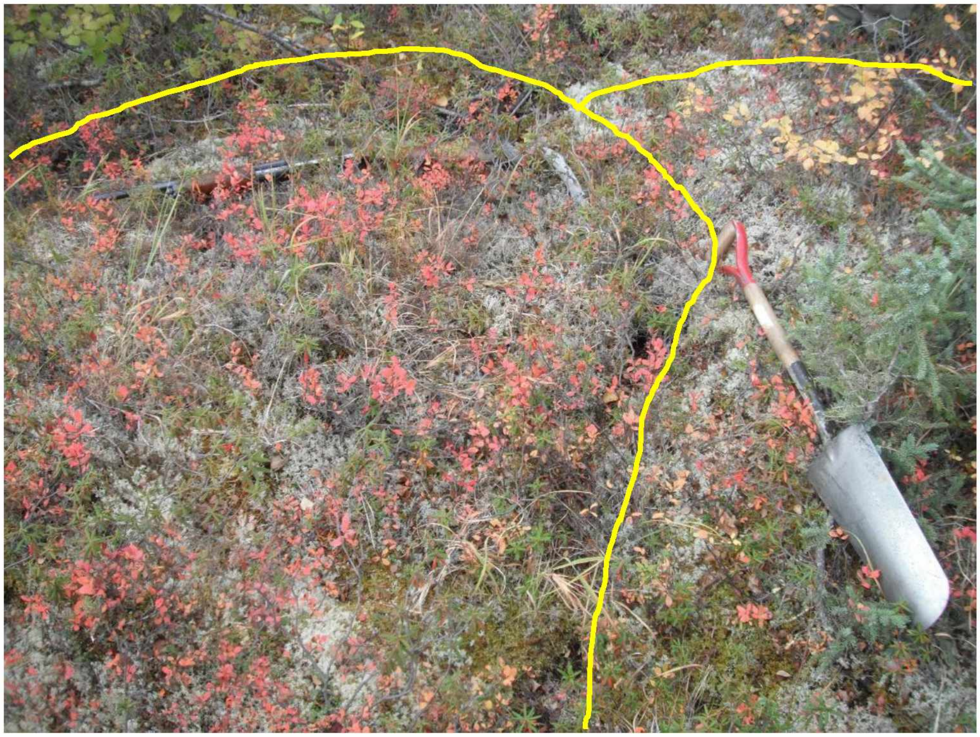


Figure 49. Frost Cracks

The slope position groups of soil profiles were studied to determine where periglacial processes were evident. A comparison of the pedon descriptions was made to determine which periglacial processes are currently active and which are relic features among the various groups of profile data. However, the influence of periglacial processes (Pidwirny, 2006) is not uniform across all the soils of the transects in this study. There is considerable evidence that the periglacial processes have mixed the soil horizons often drawing organic materials deep into the soil profile through a process referred to as cryoturbation. The two profiles on the foot slope that were most recently burned (Site 4-4 and 7-3) showed the most evidence of cryoturbation without the presence of permafrost at the time of sampling. Profiles 4-4 and 7-3 were on a gentle north aspect and appear to have been cryoturbated as a result of have having permafrost present in the profile prior to the wildland fires. The back-slope profiles developed in the skeletal parent materials along Transect 8 did not show much cryoturbation except some sites having well-developed non-sorted circles and solifluction lobes which result from freeze-thaw cycles. The southwest-facing basin studied along Transect 8 lacks permafrost because the high rock content may provide a conduit for large temperature swings within the soil profile. Non-sorted circles dominated the summit position due to strong frost action on the exposed surface. Overall 14 of 20 profiles with permafrost (70%) showed evidence of cryoturbation (Turbels) on all aspects and topographic positions.

Soil Classification

Each of the sample sites was classified according to the Soil Taxonomy (Soil Survey Staff, 2014). Table 7 shows the attributes that lead to the classification for each sample site. Below the organic horizons (O), the most common mineral horizon was a slightly modified or cambic horizon (Bw).

Soils are considered to have permafrost if they remain frozen for two consecutive years. In order to be in the Gelisols order there must be permafrost within 100 cm of the surface or cryoturbation within 100 cm and permafrost within 200 cm of the surface (Soil Survey Staff, 2014). Some of sites in this study had been burned in the previous 15 years (AFS, 2017) which may have resulted in a deepening of the active layer (seasonally thawed material) (Davis, 2001) beyond the 2-meter level and thus the burned sites would no longer be considered Gelisols although there may be permafrost at some deeper level.

The mean annual air temperatures across the study site range between -5°C and -6°C which should preserve permafrost in the soils (Jorgenson, et al., 2008). However, some sites did not exhibit the properties necessary to be classified as gelisols in the soil profiles that were excavated in this study. Sites without frozen conditions were considered cryic in nature rather than gelic. Unfrozen sites had an average temperature at 50 cm depth of + 4°C while sites with permafrost had an average temperature of -1°C at this same depth (Roth, 2012), indicating the frozen soils are very close to thawing.

Summit soils were often classified as Typic Haplocrepts or Typic Dystrocryepts and occasionally had a lithic contact. Saddle soils were often described as Ruptic Histoturbels with permafrost within less than 50 cm the surface. Shoulder soils were often described as Typic or Ruptic Histoturbels and most often had permafrost present within 50 cm of the soil surface. Back slope soils generally had permafrost present within 40 cm to 60 cm of the soil surface under the organic mat of the inter-stripe and at 80 cm to 100 cm under the lichen stripes (non-sorted circles) thus were commonly classified as Ruptic-Histic Aquiturbels. Foot slope soils were evenly split between Inceptisols (Typic Cryaquepts, Aquic Humicryepts, Lithic Dystrocryepts) and Gelisols

(Typic Histoturbels, Typic Aquiturbels, Ruptic-Histic Aquorthels) including the classifications for the pre-burned condition of sites 4-4 and 7-3.

Recent wildfire activity has substantially altered some of the conditions that were present during soil formation (Geisler & Ping, 2013) to the point that some soils now may require additions to the taxonomy classification (Soil Survey Staff, 2014) in order to capture both the present conditions and the conditions which were present during soil formation. There are likely to be soil profiles that are not easily described using the current key, in part, because the soil forming factors have changed soil conditions over time and due to broader sampling of soils in more remote areas which present new challenges for the existing system (Soil Survey Staff, 2014). Some soil profiles indicate they were likely formed when permafrost was present higher up in the soil creating a perched water table that supported a thick organic mat and water table that fluctuated resulting in both iron depletion (gleying) and redox deposits (Fe^{3+}) being formed. As the active layer has deepened substantially on some sites, the present moisture regime does not support the characteristics shown in the profile. During this study there were two profiles (4-4 and 7-3) where present conditions do not match the conditions that created the observed features. The soil survey of the White Mountains has encountered several more instances where these conditions exist (Roth, 2012). Upon completion of the Steese and White Mountains soil survey there may be sufficient evidence to support a new classification.

Freeze-thaw processes that create solifluction lobes, sorted and non-sorted circles cause the pedon to extend across a discontinuity which can also be difficult to describe in the current taxonomy. The pedon descriptions for these sites needs to include deep organic horizons with permafrost high in the profile on one side and shallow organic horizons (or bare ground) with a substantially deeper active layer (up to 1 m more) on the rest of the pedon. This complex of conditions is difficult to describe with current taxonomy rules.

Classifications Suggested

During the course of conducting the soil survey there were a few sites where it was difficult to classify the soils according the current taxonomy (Soil Survey Staff, 2014).

The first one resulted from a change in conditions between the conditions that the soils existed before and after the most recent fires. While fire is a frequent player in the region soil taxonomy sometimes has difficulty addressing the changes it brings about. The second involves the need to describe the entire pedon in a complex setting such as solifluction lobes, sorted and non-sorted circles where the pedon extends across the boundary of the feature to include the undisturbed material adjacent to it. This study has provided new data to define the taxonomic criteria of soils formed in periglacial environment in soil taxonomy.

Folistic Aquiturbel

On some sites (4-4 and 7-3) there is a dry folistic epipedon that overlays a soil with a considerably reduced matrix (occasionally as gley as N/4). On site 4-4 and 7-3 soil was apparently formed during a much colder and wetter time and could easily have been described as a Histic Aquiturbel but the conditions under which the soil profiles were formed no longer exist and may not return due in part to a loss of permafrost through deepening of the active layer after fire. Rising climatic temperatures may not allow permafrost to return to sites where permafrost has thawed below the diagnostic depth. Drainage conditions that are difficult to describe with current taxonomy rules may also be found on some steep north-facing slopes where they are too well drained to have a Histic epipedon (7-2).

Turbic Haplocryept or Turbic Dystrocryept

This Subgroup is proposed to address the sorted and non-sorted circle on ridge tops (summits and shoulders). Pedons with sorted or non-sorted circles have two very different profiles depending on where you sample the profile and whether there is permafrost present on these complex sites. They are often well drained and do not contain much ice. Frost action has created a cryoturbation without permafrost currently within 100 cm or more of the surface and resulted in the mixing of soil materials between the mineral and organic portions of the soil profile. This mixing results in the materials being adjacent to one another rather than being atop one another.

Table 7. Soil Classification

Site	Diagnostic Surface Horizon	Diagnostic Subsurface Horizon	Other Diagnostic Soil Characteristics	Soil Temperature Regime/Clas	Taxonomy Classification	Depth to Permafrost	Presence of cryo-turbation	OM depth	Depth of Observation (cm)
01-01		CR @ 35 cm	Base Saturation< 50%	Cryic	Lithic Dystrocryept	None	No	N/A	60
01-02	10 cm Organic matter	CR @ 25 cm	Bg 15- 25 cm	Cryic	Lithic Cryaquept	None	No	10 cm	80
01-03	23 cm Organic matter	CgOajjf @52 cm		Gelic	Ruptic Histoturbel	52 cm	Yes	23 cm	80
01-04	18 cm Organic matter	Cf/ Wf	Bg 32-38 cm	Gelic	Histic Aquorthel	38 cm	No	18 cm	55
02-01		Cambic horizon 5 to42 cm	Base Saturation< 50%	Cryic	Typic Dystrocryept	None	Yes	N/A	120
02-01B	28 cm Organic matter	Cambic horizon 28 to40 cm	Trough sorted circle, BS <50%	Cryic	Typic Dystrocryept	None	Yes	28 cm	
02-02	23 cm Organic matter	CRf @ 58 cm		Gelic	Lithic Histoturbel	58 cm	30 to 58 cm	23 cm	80
02-03	60 cm Organic matter			Gelic	Sphagnic Fibristel	44 cm	No	60 cm	60
02-04		Bw 8- 25 cm on CR	Buried Horizons 25 to 55 cm, Base Saturation<	Cryic	Lithic Dystrocryept	None	No	5 cm	55
03-01	25 cm Organic matter	Oejj 25 to 40 cm		Gelic	Ruptic Histoturbel	> 60 cm	21 to 40 cm	25 cm	60
03-02	22 cm Organic matter	Cryoturbation 22 to 80 cm		Gelic	Ruptic Histoturbel	46 cm	22 to 46 cm	22 cm	80
03-03R	15 to 30 cm Organic	Oajj on left side		Gelic	Ruptic Histoturbel	75 cm	Left 19 to 75 cm	30 cm	80
03-03L	40 cm Organic matter	Oajj 19 to 75 cm	60 cm mineral in top 100 cm	Gelic	Ruptic Terric Fibristel	40 cm	19 to 75 cm	40 cm	
04-01		Bw 5 to 35 cm	Base Saturation< 50%	Cryic	Typic Dystrocryept	None	No	N/A	55
04-02R	Burned 20+ cm OM??	Bg 6 to 45 cm	Before Burn??	Gelic	Ruptic-Histic Aquorthel	maybe 40 originally	2 to 95 cm	Likely >25 cm	120
04-02 Now		Bg 6 to 45 cm		Gelic	Typic Aquiturbel	> 110 cm	3 to 95 cm	3 cm	
04-02L	Burned 20+ cm OM??	Bg 6 to 45 cm		Gelic	Ruptic-Histic Aquorthel	> 110 cm	20 to 95 cm	5 cm	

Site & Date	Diagnostic surface horizon	Diagnostic subsurface horizon	Other diagnostic soil characteristics	Soil temperature regime/class	Taxonomy Classification	Depth to Permafrost	Presence of cryo-turbation	OM depth	Depth of Observation (cm)
04-03	35 cm Organic matter	Bw 35 to 55 cm	Bg 20 -40 cm	Gelic	Ruptic-Histic Aquorthel	70 cm	55 to 70 cm	35 cm	80
04-04	Burned 20+ cm OM??		Before Burn??	Cryic	Histic Cryaquept	maybe <40 originally	No	Likely >25 cm	60
04-04 now	12 cm Organic matter	Bg 12 to 20 cm	Buried Horizons 20 to 47 cm	Cryic	Typic Cryaquept	> 60 cm	No	12 cm	
05-01	37 cm Organic matter	Oajj 80 cm and deeper		Gelic	Ruptic Histoturbel	50 cm	50 to 60+ cm	37 cm	80
05-02	32 cm Organic matter	Bg 32 to 48 cm	Solifluction Lobe Cryoturbation 22 to 40 cm	Gelic	Typic Histoturbel	48 cm	Solifluction Lobe	32 cm	80
05-03 R	35 cm Organic matter	Bg 15 to 70 cm	Cryoturbation 15 to 70 cm	Gelic	Ruptic Histoturbel	70 cm	20 to 100 cm	35 cm	100
05-03 L	22 cm Organic matter		Cryoturbation right side	Gelic	Ruptic Histoturbel	20 cm	65 to 70 cm	22 cm	
05-03 C	12 cm Organic matter		Cryoturbation right side	Gelic	Ruptic Histoturbel	40 cm	15 to 35 cm	12 cm	
05-04	20 cm Organic matter	Bg 38 to 60 cm		Gelic	Typic Historthel	60 cm	No	20 cm	80
06-01	38 cm Organic matter			Gelic	Typic Historthel	53 cm	No	38 cm	80
06-02	8 cm Organic matter	Bg 35 to 82 cm		Gelic	Typic Aquiturbel	82 cm	51 to 70 cm	8 cm	100
06-03	22 cm Organic matter	Bg 26 to 50 cm		Gelic	Typic Hitoturbel	22 cm	26 to 50 cm	22 cm	100
07-01	18 cm Organic matter	Cambic 25 to 38 cm	Bg 38 to 85 cm	Gelic	Typic Aquiturbel	70 cm	38 to 85 cm	18 cm	100
07-02 R	35 cm Organic matter		gelic20 to 6o cm	Gelic	Ruptic-Histic Aquiturbel	45 cm	Unknown	35 cm	65
07-02 L	15 cm Organic matter	Cambic 15 to 60 cm	Bg 48-73 cm	Gelic	Ruptic-Histic Aquiturbel	73 cm	14 to 73 cm	15 cm	
07-03	20 cm Organic matter	Cambic 10 to38 cm	Before Burn??	Gelic	Typic Aquiturbel	maybe <40 originally	35 to 42 cm	20 cm	115
07-03 now	20 cm Organic matter	Cambic 10 to38 cm	Redox features	Cryic	Aquic Humicryept	> 115 cm	36 to 42 cm	20 cm	
08-01	10 cm Organic matter	Cambic 20 to 75 cm	Bg 40 to 75 cm	Cryic	Typic Cryaquept	None	No	10 cm	75

Site & Date	Diagnostic surface horizon	Diagnostic subsurface horizon	Other diagnostic soil characteristics	Soil Temperature Regime/class	Taxonomy Classification	Depth to Permafrost	Presence of cryo-turbation	OM depth	Depth of Observation (cm)
08-02	15 cm Organic matter	Cambic 18 to 100 cm	Water & Mud Flow into Pit	Cryic	Typic Cryaquept	None	No	15 cm	100
08-03 R	16 cm Organic matter	Cambic 18 to 60 cm	Non-sorted Stone Circle, Base Saturation< 50%	Cryic	Lithic Dystrocryept	None	No	16 cm	80
08-03 L	10 cm Organic matter	Cambic 18 to 60 cm	Non-sorted Stone Circle, Base Saturation< 50%	Cryic	Lithic Dystrocryept	None	No	10 cm	
08-04	18 cm Organic matter	Cambic 26 to 105 cm	Bg 50 to 105 cm	Cryic	Histic Cryaquept	None	No	18 cm	105
09-01		Cambic 4 to 59 cm	Bg 30 to 59 cm, BS >50%	Cryic	Aquic Haplocryept	None	Yes	4 cm	80
09-02		Cambic 0 to 15 cm	CR at 50 cm, BS < 50%	Cryic	Lithic Dystrocryept	None	No	None	50
09-03		Cambic 7 to 82 cm	Bg 35 to 80 & Cg to 100 cm	Cryic	Typic Cryaquept	None	Yes	7 cm	100
10-01		Cambic 0 to 8 cm	CR at 25 cm, BS < 50%	Cryic	Lithic Dystrocryept	None	No	None	50
10-02	30 cm Organic matter	Cambic 38 to 55 cm	Bg 30 to 55, Cg 85 - 100 cm	Gelic	Typic Historthel	85 cm	No	30 cm	100
10-03	22 cm Organic matter	Cambic 22 to 38 cm	Bg 32 to 38 cm	Gelic	Typic Historthel	50 cm	No	22 cm	80

THIS PAGE LEFT BLANK INTENTIONLLY

CONCLUSION

The objectives of this study were to investigate the soil landscape relationships along toposequences in a selected alpine environment in the boreal region of Alaska, to characterize the soils and to examine the current taxonomic criteria on soils affected by periglacial processes. Topographic transects generally began on the summits and proceeded downhill on a variety of slope positions and aspects to describe the soils at various spacings along the transects. Periglacial processes manifested through repeated freeze-thaw cycles play a controlling role in

Periglacial processes have produced unique micro relief in the form of patterned ground that controls the vegetation community and has modified the soil texture by presence of rock fragments. The presence of permafrost within the sampling depth was related to the vegetative community, the absence of coarse rock fragments or lithic contact and the time since the last wildfire event. Cryoturbation was indicated by the churning of organic matter down into mineral horizons. Broken and warped horizons are evident in soils affected by permafrost and was found at all topographic positions except the summits.

Overall there were few significant patterns that could be described based on the 35 sites spread across 5 slope positions and 4 aspects for this study. Organic horizons ranging from 4 to 80 cm (average 26 cm) formed on most sites except the summits. The pH values of the O horizons were consistently about one full unit lower than that of the underlying horizons indicating a limited influence of vegetative matter and organic acids derived from decomposition in modification of the deeper soil horizons due to limited leaching. However, the low pH (5.5) of the mineral soils in the Steese Mountains is likely to limit vegetative potential. Permafrost was present in 57% of the studied sites and appeared to have been present in 6 more sites prior to wildfire activity. Contrary to the findings of the relationships between aspect and or elevation (Ping, et al., 2017a, 2017b, Washburn, 1973), this study did not identify any pattern of permafrost presence or depths associated with aspect or elevation. One explanation for not identifying a permafrost pattern on south aspects might be that only Transect 8 (aspect 205^{o}) and Transect 6 (aspect 154^{o}) were close to a south aspect. Transect 8 had a high coarse rock fragment content without permafrost. High rock fragments in the soils conduct solar energy rapidly in the summer and also alter the porosity, thus increasing the internal drainage on this southerly aspect transect. The combined effects of coarse rock fragments and increased drainage tend to facilitate the deepening of the active layer beyond 1 m in finer textured soils. In most coarse-textured or skeletal soils, the summer thaw can easily reach the paralithic or lithic contact but could still have permafrost at or below 2m. Either case could meet the requirement for Gelisols. Although Ping, et al., (2005b; 2017b) and others have indicated that it is not common for permafrost to exist on south aspect slopes; yet, in this study permafrost was found at all sites of Transect 6. Permafrost on Transect 6 is likely due to the presence of spruce forest and forest floor dominated by moss rather than willow bush vegetation on the site which provide more shade thus retards spring snow melt and thawing of seasonal frost.

The surface organic horizons were responsible for most of the elevated levels of carbon, nitrogen, and other nutrients measured in this study. Elevated surface nutrient levels are related to the decomposition of the organic matter and rapid uptake of nutrients since most root systems are heavily concentrated within the organic horizons. Nutrient levels dropped rapidly with depth as the various mineral horizons were encountered. All of the nutrients that were analyzed for each profile generally tracked the same pattern of loss with depth of the other nutrients for the same profile. Profiles which were more variable for one analyte were most often highly variable for several of the analytes.

When descending from the rocky summits, the rock fragments were lowest in the saddles and then gradually increased along the topo sequence as the elevation declined. Increasing rock fragments at lower slope positions was the only parameter that showed a linear change with elevation or aspect. This may partially be attributed to water and wind erosion loss of fine soil particles from the summits and colluvial movement of rock fragments down slope.

The parent materials in the study areas exert dominating effects in soil chemical properties. In the Steese Mountains the soil parent material was primarily derived from the Birch Creek Schist which is slightly acidic in nature. This parent material partially explains the acid soils reactions and the low base saturation in most soil horizons in the Steese Mountains. The Crazy Mountains (Transects 9 and 10) presented more basic parent materials with some calcareous material present. The Crazy Mountains had an elevated pH, although still slightly acidic, but was otherwise similar to the rest of the transect data and the general data trends and nutrient levels.

The cold climate and short growing season limit the biological activity in any given season delaying the effects of biological activity and organic acids on soil formation. The freeze-thaw cycles do promote the slow mechanical breakdown of parent material over long periods of time. Seasonal frost may temporarily perch water within the profile creating highly reduced horizons during the spring which give way to a more aerated profile during the summer which allows for formation of ferric minerals. Soil horizonation is weakly expressed throughout the study area. The most common diagnostic horizon is the cambic horizon and was present in 21 of the 35 profiles (Appendix 3). Where permafrost was not present, soils were classified as Inceptisols similar to what Ping, et al., (2006, 2017b) noted for soils in the boreal forest region of Alaska.

The soil analyses performed for this study will provide the basis for the NRCS to describe the soil properties in the broader soil survey of the Steese and White Mountains area. This study will also be helpful in analyzing the vegetation data to develop the ecological site descriptions and the state and transition models for the soil survey area.

For land management, the summits will provide the most stable locations for trails or roads but saddles may be difficult to cross due to the higher moisture content and finer grained soils thus requiring additional engineering attention. South facing slopes and areas with high coarse rock fragment content are less likely to have permafrost in the upper portion of the soil profile making these permafrost free sites more desirable for travel routes and structure placement. Where back slopes have larger solifluction lobes they tend to be less stable due to increased freeze-thaw action and would be more difficult for placement and maintenance of roads, trails and/or structures.

Future Actions

Expanded Analysis of Permafrost

This study only used the 35 soil profiles where soil samples were collected for laboratory analysis. The entire White and Steese Mountains Natural Resources Conservation Service (NRCS) Soil Survey has collected approximately 1,500 profiles from across a broader area. An analysis of the entire Steese and White Mountains data set to look into the effects of fire, presence of permafrost and the effects of other periglacial processes could be made based on topographic position and aspect. This type of analysis would be much more robust and statistically sound but would lack the intense chemical and particle analysis of this study since samples have only been collected from a very limited number of locations for analysis at the NRCS national laboratory in Lincoln, Nebraska.

REFERENCES

AFS. (2016). *Alaska Interagency Wildland Fire.* Fairbanks, ALASKA: Alaska Interagency Fire Center.

AFS. (2017). *Fire History.* Fairbanks, ALASKA: Alaska Interagency Fire Center. Retrieved from https://afsmaps.blm.gov/imf_firehistory/imf.jsp?site=firehistory

AgSource. (2014). *Cation Exchange Capacity and Base Saturation.* University of Georgia, UGA Extension. Athens: University of Georgia. Retrieved March 2018, from crinet.com/AgSource-Cooperative-Services.

Augustinus, P. (2002). Periglacial research in New Zealand: a review: Periglacial and Permafrost Research in the Southern Hemisphere. *South African Journal of Science, 98*(1-2), pp. 64 - 67.

Bockhein, J. G., & Ugolini, F. C. (1990a). Review of pedogenic zonation in well drained soils of the Southern circumpolar region. *Quaternary Research, 34*(1), pp. 47-66.

Bockhiem, J. G. (1990b). Soil Development Rates in the Transantarctic Mountains. *Geoderma, 47*(1-2), pp. 59 - 77.

Brown, J., & Kreig, R. A. (1983). *Guidebook to Permafrost and related features along the Elliott and Dalton Highways, Fox to Prudhoe Bay, Alaska.* Fairbanks: Alaska Division of Geological and Geophysical Surveys, Department of Natural Resources.

Campbell, I. B., & Claridge, G. C. (2004). *Cryosols - Permafrost -Affected Soils* . (J. M. Kimble, Ed.) Berlin: Springer-Verlag.

Chapman, R. M., Weber, F. R., & Taber, B. (1971). *Preliminary Geologic map of Livengood Quadrangle, Alaska.* Open File Report 483, 1:250,000 scale, US Dept of Interior, USGS, Reston, VA.

Davis, T. N. (2001). *Permafrost: a Guise to Frozen Ground in Transition.* Fairbanks: University if Alaska Press.

Day, P. (1965). Particle Fractionation and Particle-Size Analysis, Hydrometer Method, in Methods of Soil Analysis, Part 1. *Agronomy*, 9:562-66.

Dryness, C. T., Viereck, L. A., & Van Cleve, K. (1986). Fire in taiga communities of interior Alaska. In K. Van Cleve, F. S. Chapin, P. W. Flanagan, L. A. Viereck, & C. T. Dryness (Eds.), *Forest Ecosystems in the Alaskan Taiga. Ecological Studies (Analysis and Synthesis* (Vol. 57, p. 74 to 86). New York: Springer.

Eberlein, D. a. (1988). *Correlation of Precambrian Rocks of the United States and Mexico, Precambrian Rocks of Alaska.* (1988-573-047166,102 Region No. 8 ed.). U.S. Government Printing Office.

Fisher, D. B. (2017). *ALASKA Snow Daily Data Summaries - Eagle Summit.* (D.B. Fisher Hydrologist (Data Collection Officer), Ed.) Retrieved October 15, 2017, from Alaska Snow,Water and Climate Services: http://ambcs.org

Foster, H. L. (1992). *Geologic map of the eastern Yukon-Tanana Region, Alaska: USGS Open-File Report 92–313.* Open file.

French, H. (2007). *The Perigalcial Environment* (3rd ed.). West Sussex, England: John Wiley and Sons.

French, H., & Shur, Y. (2010, August). The principles of cryostratigraphy. *Earth-Science Reviews, 101*(3–4), pp. 190-206.

Geisler, E. S., & Ping, C. L. (2013). Effects of periglacial processes on soil formation in Subarctic Alaska. *In Abstracts of the Soil Science Society of America annual meetings.* Tampa, Florida: scisoc.confex.com.

Goldthwait, R. (1976). Frost sorted patterned ground: A review. *Quaternary Research, 6*(1), pp. 27-35.

Hanson, H. C. (1950, OCtober). Vegetation and Soil Profiles in some Solifluction and Mound Areas in Alaska. *Ecology, 3*(4), pp. 606-630.

Höefle, C., Ping, C. L., & Kmble, J. M. (1998). Properties of Permafrost Soils on the Northern Seward Peninsula, Northwest Alaska. *Soil Science Society of Am J, 62*(1), pp. 629-1639.

Hugelius, G., Kuhhry, P., Tarnocai, C., & Virtanen, T. (2010). - Soil organic carbon pools in a periglacial landscape: a case study from the Central Canadian Arctic. *Permafrost and Periglacial Processes, 21*(1), pp. 16-29.

Jenny, H. (1941). *Factors of Soil Formation.* New York, USA: McGraw-Hill.

Jorgenson, M. T., Yoshikawa, K., Kanevskiy, M., Shut, Y., Romanovsky, V., Marchenko, M., . . . Jones, B. (2008). *Permafrost characteristics of Alaska, map.* Univ. of Alaska Fairbanks, Inst. of North. Eng, Fairbanks.

Juday, G. (1988). *Alaska research natural areas: 1. Mount Prindle.* Portland: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station Portland, OR.

Krantz, W. (1990). Self-organization manifest as patterned ground in recurrently frozen soils. *Earth-Science Review, 29*(1-4), pp. 117-130.

Mackay, J. R. (1995). Active Layer Changes (1968 to 1993) Following the Forest-Tundra Fire near Inuvik, N.W.T., Canada. *Arctic Alpine Research, Vol. 27, No. 4*, pp. 323-336.

Michaelson, G. J., Ping, C. L., & Candler, R. J. (1993). *Methods of Soil and Plant Analysis: University of Alaska Fairbanks Soil and Plant Analysis Laboratory.* Palmer,ALASKA: Palmer Research Center, Palmer, ALASKA.

Michaelson, G. J., Ping, C.-L., & Clark, M. H. (2013). Soil Pedon Carbon and Nitorgen Data for Alaska: An Analysis Update. *Open Journal of Soil Science*.

NRCS. (2006). *Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin.* USDA Natural Resources Conservation Sevice, Wahington, DC.

NRCS. (2017). *NRCS Weather & Climate.* USDA- NRCS. Retrieved October 2017, from http://www.wcc.nrcs.usda.gov/nwcc, Parfitt, R. L., & Childs, C. W. (1988). Estimation of forms of Fe and Al-a review, and analysis of contrasting soils by dissolution and Mossbauer methods. *Australian Journal of Soil Research*, 26:121-144.

Péwé, T. (1975). *Quaternary Geology of Alaska.* US Department of Interior. Washington: US Geological Survey. Retrieved January 14, 2018

Pidwirny, M. (2006). Periglacial Processes and Landforms. In M. Pidwirny, *Fundamentals of Physical Geography* (2nd Edition ed., p. Viewed @ www.PhysicalGeography.net/ Fundamentals/10ag.html).

Ping, C. L., Bockheim, J. G., Michaelson, G. J., & Walker, D. A. (1998). Characteristics of Cryogenics Soils along a Latitudinal Transect in Arctic Alaska. *Journal of Geophysical Research, 103*(D22), pp. 28917-29828.

Ping, C. L., Boone, R. D., Clark, M. H., Packee, E. C., & Swanson, D. K. (2006). State Factor Control of Soil Formationin Interior Alaska. In F. S. Chapin III, M. W. Oswood, K. Van Cleve, L. A. Viereck, & D. L. Verbyla, *Alaska's Changing Boreal Forest* (pp. 21-38). New York: Oxford Press.

Ping, C. L., Clark, M. H., Kimble, J. M., Michaelson, G. J., Shur, Y., & Stiles, C. A. (2012). Sampling protocols for Permafrost-Affected Soils. Soil Horizons. *doi:10.2136/sh1*, 2-09-0027.

Ping, C. L., Clark, M. H., Michaelson, G. J., D'Amore, D., & Swanson, D. K. (2017b). Soils of Alaska. In L. T. West, M. J. Singer, & A. E. Hartemink (Eds.), *Soils of the USA* (pp. pp. 329-350). Springer.

Ping, C. L., Michaelson, , G. J., Malone, T., Packee, E. C., Wilson, L. A., Zaman, N. D., . . . Kimble, J. M. (2017a). *Physio-chemical environment, morphology, characterization and classification of soils associated with black spruce in Alaska.* Agricultural and Forestry Experiment Station Bulletin #117, School of Natural Resources and Extension, University of Alaska Fairbanks, Agricultural and Forestry Experiment Station, Fairbanks, ALASKA.

Ping, C. L., Michaelson, G. J., Kimble, J. M., & Walker, D. A. (2005a). *Soil Acidity and Echange Properties of Cryogenic Soils in Arctic Alaska.* Fairbanks: UAF.

Ping, C. L., Michaelson, G. J., Packee, E. C., Stiles, C. A., Swanson, D. K., & Yoshikawa. (2005b, September 29). Soil Catena Sequences and Fire Ecology in the Boreal Forest of Alaska. *Soil Science Society of America Journal, 69*, pp. 1761-1772.

Ping, C. L., Shoji, S., Ito, T., Takahashi, T., & Moore, J. P. (1989, July). Characterisitics and Classification of Volcanic Ash-Derived Soils in Alaska. *Soil Science, 48*(1), pp. 8-28.

Roth, N. (2012). *White Mountains Soil Survey.* NRCS Steese- White Mountains Soil Survey - unpulbished data, Fairbanks, ALASKA.

Schoenberger, P. J., Wysocki, D. A., & Benham, E. C. (2012). *Field book for describing and sampling soils* (Version 3.0. ed.). (S. S. Staff, Ed.) Lincoln, NE: Natural Resources Conservation Service, National Soil Survey Center.

Schroeder, M. J., & Buck, C. C. (1970). *Fire Weather.* USDA Forest Service.

Slaymaker, O. (2011). Criteria to distinguish between periglacial, proglacial and paraglacial environments. *Quaestiones Geographicae 30(1), Bogucki Wydawnictwo Naukowe, Poznań, 30*(1), pp. 85–94.

Soil Science Society of America. (2008). *Soil Terminologyy Glossary.* Soil Science Society of America. Retrieved 2017, from www.soils.org/publications/soils-glossary/>

Soil Survey Laboratory Staff. (1996). *Soil Survey Laboratory Methods Manual.* Lincoln, NE: USDA Natural Resources Conservation Service, National Soil Survey Center.

Soil Survey Staff. (2014). *Keys to Soil Taxonomy.* (Vol. Twelfth Edition). USDA Natural Resources Conservation Service National Soil Survey Center, Linclon, NE.

Sonon, L. S., Kissel, D. E., & Uttam, S. (2014). *Cation Exchange Capacity and Base Saturaton.* Athens: University of Georgia Extension.

Spitzer, M., Wildenhein, J., Rappsiber, J., & Tyers, M. (2014). Box Plot R: a web tool for generation of box plots,. *Nature Methods, 11, doi:10.1038/nmeth.2811*, pp. 121–122. Retrieved from http://shiny.chemgrid.org/boxplotr/

US Climate Data. (2017). *US Climate Data*. Retrieved October 15, 2017, from Climate Central - Alaska and Weather Averages Central: http://www.usclimatedata.com/climate.php

Viereck, L. A. (1983). The Effect of Fire in Black Spruce Ecosystems of Alaska and Northern Canada. In R. W. Wien, & D. A. MacLean (Eds.), *The Role of Fire In Northern Circumpolar Ecosystems.* John Wiley and Sons Ltd.

Viereck, L. A., Dryness, C. T., & Foote, M. J. (1993). An Overview of Vegetation and soils of the Foodplain Ecosystems of the Tanana River, Interior Alaska. *Canadian Journal of Forest Research, 23*, pp. 889-898.

Viereck, L. C. (1992). *The Alaskan Vegetation Classifications.* USAD US Forest Service.

Wahrhaftig, C. (1965). *Physiographic divisions of Alaska. US.* Washington, DC: US Geological Survey.

Washburn, A. (1973). *Periglacial processes and environments.* New York: St. Martin's Press.

Weather Base. (2017). *MONTHLY - WEATHER AVERAGES SUMMARY- Central, Alaska*. Retrieved October 15, 2017, from Central, Alaska Travel Weather: http://www.weatherbase.com/weather/weather.php3?s=664105&cityname=Central-Alaska-United-States-of-America

APPENDICES

APPENDIX A – Maps

APPENDIX B – Field Site Locations

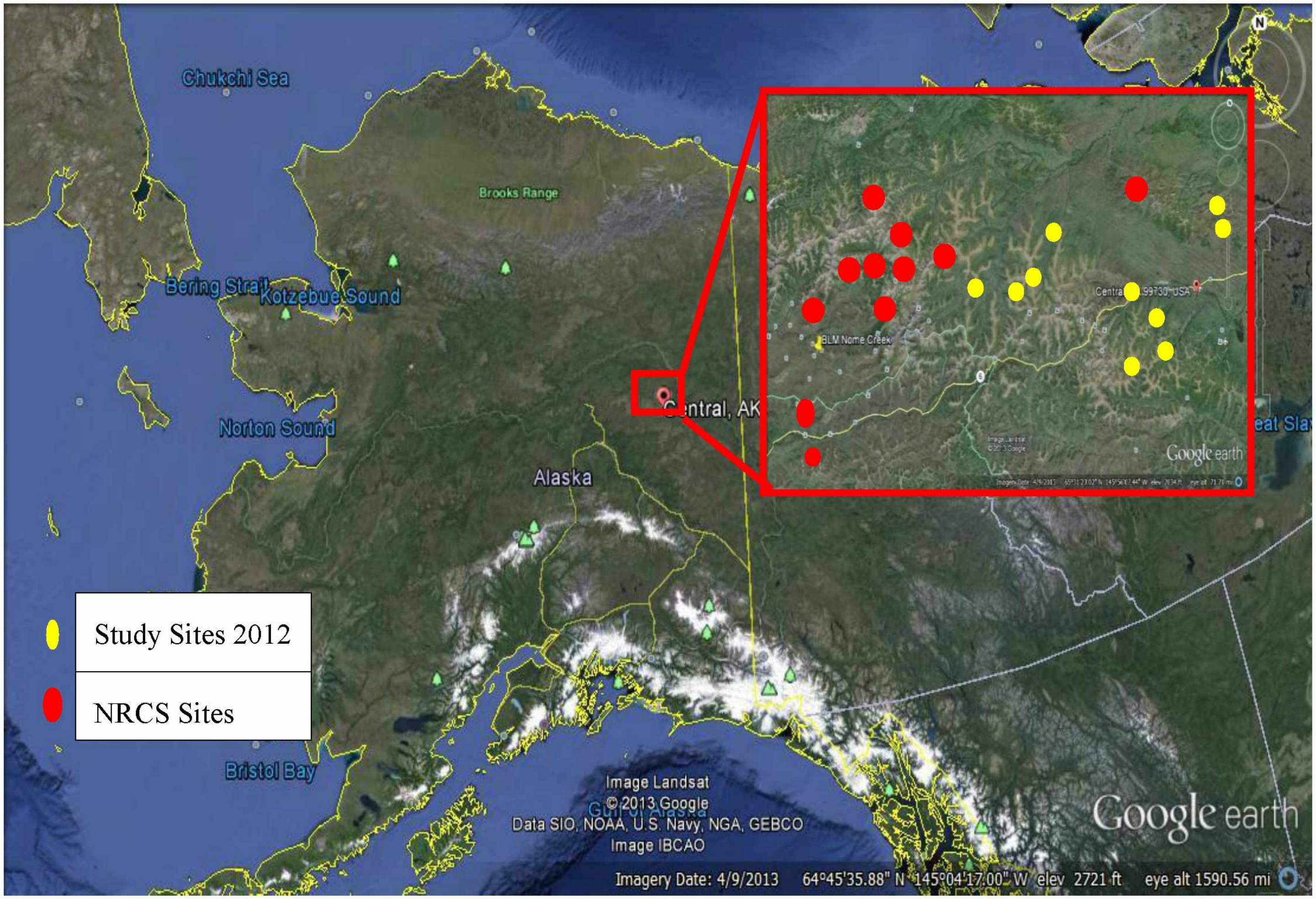
APPENDIX C - Soil morphological and physical properties of the toposequence study sites in the Steese and White Mountains area, Alaska

APPENDIX D - Soil Chemical Properties of the toposequence study sites in the Steese and White Mountains area, Alaska

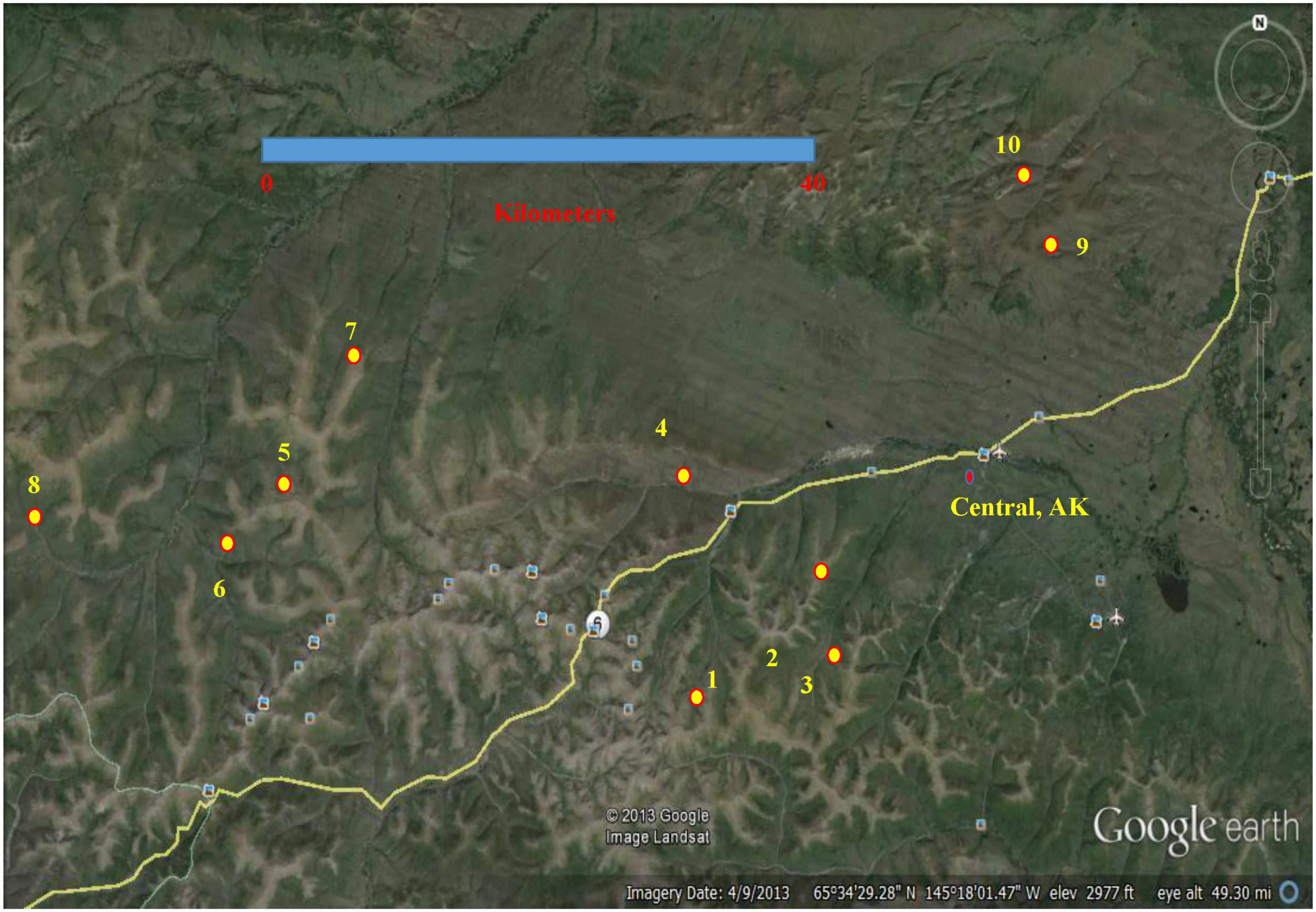
APPENDIX E - Extractable Iron – Aluminum of the toposequence study sites in the Steese and White Mountains area, Alaska

APPENDIX A – Maps

Study Location



Sample Sites



25

APPENDIX B. Physiographic environment of study sites in the Steese and White Mountains area, Alaska

Site Code	Lat. ºN	Long. ºN	Elev.		Landscape	Landform	Microtopography	Slope	Aspect	Land Cover
			m. asl	ft. asl				%	degree	
01-01	65.4540	145.2240	975	3199	mountains	summit	stone pavement	0	90	alpine tundra
01-02	65.4540	145.2230	973	3192	mountains	shoulder/upper	solifluction lobe	10	103	shrub tundra
01-03	65.4544	145.2222	970	3182	mountains	shoulder/lower	tussock	8	113	tussock tundra
01-04	65.4561	145.2075	796	2612	mountains	backslope	complex slope	26	70	forest tundra
02-01	65.5286	145.0167	851	2792	mountains	summit	non-sorted circle	4	130	shrub tundra
02-02	65.5278	145.0117	801	2628	mountains	back slope/up	solifluction lobe	22	115	forest tundra
02-03	65.5281	145.0083	778	2552	mountains	back slope/mid		25	90	shrub tundra
02-04	65.5264	144.9978	631	2070	mountains	back slope/low		35		forest (PIMA)
03-01	65.4628	146.0203	1021	3350	mountains	shoulder	solifluction lobe	22	292	alpine tundra
03-02	65.4639	145.0325	896	2940	mountains	saddle	earth hummock	6	280	alpine tundra
03-03	65.4628	145.0433	782	2566	mountains	back slope	stripes	15	260	forest (PIMA)
04-01	65.5730	145.2242	893	2930	mountains	summit	stone pavement	2	200	alpine tundra
04-02	65.5758	145.2244	876	2874	mountains	shoulder	earth hummock	7	0	alpine tundra
04-03	65.5811	145.2228	811	2661	mountains	back slope	moss mound	14	280	forest, burned
04-04	65.5900	145.2197	662	2172	mountains	foot slope		14		forest, burned
05-01	65.5725	145.8055	1016	3333	mountains	saddle	tussocks			alpine bog
05-02	65.5767	145.8128	1003	3291	mountains	shoulder/upper	solifluction lobe	6	280	alpine tundra
05-03	65.5755	145.8236	933	3061	mountains	back slope	stripes, solifluction lobe	22	270	shrub tundra
05-04	65.5750	145.8311	887	2910	mountains	back slope	hummocky	25	290	shrub tundra
06-01	65.5353	145.9047	860	2822	mountains	shoulder	stripes	22	128	forest
06-02	65.5319	145.9028	798	2618	mountains	back slope	hummocky	20	145	forest
06-03	65.5250	145.8992	674	2211	valley	back slope	solifluction lobe	20	190	forest, mixed
07-01	65.6639	145.7811	699	2293	mountains	shoulder	tussocks	10	340	forest tundra
07-02	65.6700	146.7825	655	2149	mountains	back slope/mid	hummocky	5	350	forest tundra

07-03	65.6811	145.7812	584	1916	valley	foot slope/ terrace		15	40	forest (PIMA)
Site Code	Lat. ºN	Long. ºN	Elev.		Landscape	Landform	Microtopography	Slope	Aspect	Land Cover
			m. asl	ft. asl				%	degree	
08-01	65.5631	146.2005	944	3097	mountains cirque	back slope/upper		20	190	shrub (Salix)
08-02	65.5628	146.2000	940	3084	mountains cirque	back slope	sorted circles	25	200	alpine tundra
08-03	65.5614	146.1961	931	3054	mountains cirque	back slope	stone circles	18	210	alpine tundra
08-04	65.5600	146.1928	932	3058	mountains cirque	back slope	moss mound	24	225	alpine tundra
09-01	65.6972	144.6208	703	2306	hills	back slope		17	110	burned PIMA
09-02	65.7000	144.5975	583	1913	hills	back slope	block field	28	130	forest, burned
09-03	65.7000	144.5833	513	1683	hills	foot slope				woodland, burned
10-01	65.7375	144.7064	838	2749	mountains	summit		1	20	subalpine shrubland
10-02	65.7407	144.7125	722	2369	mountains	back slope/upper	hummocky	22	320	forest
10-03	65.7444	144.7131	675	2215	mountains	foot slope		20	330	forest

APPENDIX C. Soil morphological and physical properties of the toposequence study sites in the Steese and White Mountains area, Alaska

Transect	Site & Date	Horizon	Depth	Munsell Color	Redoximorphic Features	Texture	Sand	Silt	Clay	Rock Fragment (>2mm)	Moist Bulk density	Dry Bulk density	Roots [1]	Slope position	Taxonomy
			cm	(moist)			%	%	%	%	Mg m-3	Mg m-3			
1	01-01	A	0-5			Loam	47	37	16	93			3F, 1M	Summit	Lithic Dystrocryept
	8/24/2012	Bw1	5-11	10YR 3/2		Silt loam	24	59	18	82			2F, 2M		
		Bw2	11-18	10YR 4/3		Silt loam	29	53	18	85			1F		
		Bw3	15-35	10YR 3/3		Silt loam	34	51	15	92			1F		
		CR	35-50	10YR 4/3						95					
	01-02	Oi BD					na	na	na	6	0.4389	0.1888		Shoulder	Lithic Cryosaprist
	8/24/2012	Oi	0-5	5YR 2.5/2			na	na	na	3			3F, 3M, 2C		
		Oe	5-10	7.5YR 2.5/2			na	na	na	3			3F, 2M		
		Oa	10-15	7.5YR 2.5/3			na	na	na	1			3F,1M		
		Oa BD					na	na	na		0.8930	0.4633			
		Bw	15-25	10YR 4/4		Loam	47	38	16	10			4F		
		Bw BD					na	na	na	1	1.1623	0.5940			
		Bg	15-25	10YR 4/4		Silt Loam	26	60	15	13					
		CR	25-35	5Y 4/1											
	01-03	Oi BD	0-9	7.5YR 2.5/2			na	na	na	8	0.5973	0.1078	4F, 2M	Low Shoulder	Ruptic Histoturbel
	8/24/2012	Oa BD					na	na	na	1	1.2467	0.6233			
		Oa	9-23	7.5YR 2.5/1			na	na	na	1			4F, 2M		
		Bg1 BD					na	na	na	1	2.0400	1.5990			
		Bg1	23-38	5Y 4/1	F3M MAT 7.5YR 4/6	Silt Loam	17	67	16	7			2F		
		Bg2 BD					na	na	na	2	1.9840	1.5173			
		Bg2	38-52	5Y 4/1	F3M MAT 7.5YR 4/6	Silt Loam	21	63	17	11			IF		
		Cg/Oajjf	52-80	5Y 3.5/1		Silt Loam	16	68	16	4					

Transect	Site & Date	Horizon	Depth	Munsell Color	Redoximorphic Features	Texture	Sand	Silt	Clay	Rock Fragment (>2mm)	Moist Bulk density	Dry Bulk density	Roots [1]	Slope position	Taxonomy
			cm	(moist)			%	%	%	%	Mg m-3	Mg m-3			
1	01-04	Oi BD	0-12				na	na	na	5	0.1806	0.0557	4VF, 3F, 2M	Backslope	Ruptic-Histic Aquorthel
	8/24/2012	Oe BD	12-18	7.5YR 3/2			na	na	na	3	0.3217	0.0556	3F, 2M		
		Bw1	18-25	7.5YR 4/2		Loam	36	50	14	56			2F		
		Bw2	25-32	7.5YR 4/4		Sandy Loam	52	35	12	41			1F		
		Bg	32-38	5Y 4/1			43	43	14	38					
		Cf/Wf	38-80	2.5Y 4/2		Loam	41	45	14	43					
2	02-01	Oi	0-12	7.5YR 4/3			na	na	na	8			4F, 4M, 2C	Summit	Typic Dystrocryept
	8/25/2012	Oa	12-28	5Y 3/3			na	na	na	11			3F, 2M		
		Bw	28-40	2.5Y 4.5/3		Loam	40	47	12	31			2F		
		A	0-5	2.5Y 4/3		Sandy Loam	55	33	12	81			5F, 2M		
		Bw1	5-18	2.5Y 5/2		Loam	44	43	13	46			1F		
		Bw2	18-42	2.5Y 5/2		Loam	46	37	17	68			3F, 1M		
		BC	42-80	2.5Y 4/2		Loam	44	37	19	67			1F		
	02-02	Oi BD	0-14	7.5YR 2.5/2			na	na	na	15	0.3332	0.1376	4F, 2M	Shoulder	Lithic Histoturbel
	8/25/2012	Oa BD					na	na	na	0	1.2803	0.5337			
		Oa	14-23	5Y 2.5/1			na	na	na	1			3F, 2M		
		A BD					na	na	na	2	1.4147	0.7093			
		A	23-30	7.5YR 2.5/1		Sandy Loam	53	38	10	7			2F, 1M		
		Bw/Ajj BD					na	na	na	0	1.4180	0.7160			
		Bw/Ajj	30-48	7.5YR 2.5/1		Loam	49	40	11	12			1F		
		A/BwjjF	48-58	7.5YR 2.5/1.5		Loam	45	41	14	14					
		Cf	58-80												

Transect	Site & Date	Horizon	Depth	Munsell Color	Redoximorphic Features	Texture	Sand	Silt	Clay	Rock Fragment (>2mm)	Moist Bulk density	Dry Bulk density	Roots [1]	Slope position	Taxonomy
			cm	(moist)			%	%	%	%	Mg m-3	Mg m-3			
2	02-03	Oi1	0-36	7.5YR 6/3			na	na	na	6			3M	Low Shoulder	Sphagnic Fibristel
	8/25/2012	Oi2	26-44	7.5YR 4/3			na	na	na	4			2F, 2M		
		Oaf	44-60	7.5YR 3/1			na	na	na	6					
		Cf	60+	2.5Y 3/2											
	02-04	Oi	0-5	7.5YR 4/3			na	na	na	9			3F, 2M, 1C	Backslope	Lithic Dystrocryept
	8/25/2012	Oa	5-8	7.5YR 4/2			na	na	na	13			3F, 2M, 1C		
		Bw	5-25	10YR 4/4		Loam	41	36	24	43			5F. 2M		
		Ab	25-33	10YR 3/2		Sandy Clay Loam	58	20	22	84			3F, 2M		
		Bwb	33-55	2.5Y 4/3		Sandy Loam	67	22	12	88					
3	03-01	Oi BD	0-8	5YR 4/4			na	na	na	6	0.1431	0.0652	5F, 2M	Shoulder	Ruptic Histoturbel
	8/26/2012	Oa BD					na	na	na	0	0.8543	0.4153			
		A1	8-15	5YR3/1		Silt Loam	33	54	14	0			4F, 1M		
		A BD					na	na	na	0	1.2970	0.5420			
		A2	15-21	7.5Y 3/2		Silt Loam	29	58	14	0			3F		
		Oajj	21-25	5YR 2.5/1			na	na	na	18			3F		
		Bw	25-40	10YR 4/2		Loam	34	45	21	70			1F		
		Bg	40-60	2.5Y 4/1.5		Sandy Loam	54	35	11	30			1F		

Transect	Site & Date	Horizon	Depth	Munsell Color	Redoximorphic Features	Texture	Sand	Silt	Clay	Rock Fragment (>2mm)	Moist Bulk density	Dry Bulk density	Roots [1]	Slope position	Taxonomy
			cm	(moist)			%	%	%	%	Mg m-3	Mg m-3			
3	03-02	Oi BD	0-8	7.5YR 2.5/3			na	na	na	17	0.3791	0.1893	4F, 4M, 1C	Saddle	Ruptic Histoturbel
	8/26/2012	Oe BD	8-13	5YR 2.5/2			na	na	na	9	0.8096	0.2803	3F, 2M, 1C		
		Oa BD					na	na	na		1.2480	0.6160			
		A	13-22	5YR 2.5/1		Silt Loam	34	56	10	13			3F, 2M		
		Bg/Oajj BD				Silt Loam	na	na	na	13	2.0873	1.6417			
		Bg/Oajj	22-46	2.5Y 4/2			34	51	15	8			1F, 1M		
		Ajj BD					na	na	na	2	1.5740	0.8743			
		Ajj	22-30	10YR 3/2		Silt Loam	29	67	5	9			4F, 2M		
		Bg/Oajj	30-46	2.5Y 4/2		Silt Loam	31	62	7	3					
		Cgf	46-80	10Y 4	F3M PL 5YR 4/6	Loam	36	47	18	10					
	03-03R	Oi BD	0-8	5YR 4/2			na	na	na	6	0.1667	0.0929	4F, 1M	Backslope	Ruptic Histoturbel
	8/26/2012	Oe BD	8-18	5YR 3/2			na	na	na	5	0.6433	0.3362	5F, 2M, 1C		
		Bw1	18-75	10YR 4/2		Loam	35	42	23	74			2F		
		Bw2	75-80	10YR 4/2		Loam	32	46	23	27					
	03-03L	Oi BD	0-20	5YR 4/2			na	na	na	5	0.3672	0.0586		Backslope	Ruptic Histoturbel
	8/26/2012	Oajj BD					na	na	na	2	0.5974	0.0942			
		Oajj	20-60	5YR2.5/1			na	na	na	1			2F		
		Cgf	60-80	10YR 4/2	F2M MAT 5Y 4/1 F3M PL 7.5YR 4/4	Silt Loam	31	58	11	67					
4	04-01	A	0-5	10YR 3/2		Sandy Loam	58	30	13	81			4F, 3M	Summit	Typic Dystrocryept
	8/27/2012	Bw1	5-20	10YR 4/2		Sandy Loam	56	29	15	79			2F, 1M		
		Bw2	20-35	7.5YR 4/4		Silt Loam	23	57	21	70					
		BC	35-55	10YR 4.5/3		Sandy Loam	54	29	18	94					
		Cf													

Transect	Site & Date	Horizon	Depth	Munsell Color	Redoximorphic Features	Texture	Sand	Silt	Clay	Rock Fragment (>2mm)	Moist Bulk density	Dry Bulk density	Roots [1]	Slope position	Taxonomy
			cm	(moist)			%	%	%	%	Mg m-3	Mg m-3			
4	04-02R	Oe	0-3	10YR 2/2			na	na	na	16			2F	Shoulder	Burned Ruptic-Histic Aquorthel
	8/27/2012	Ajj	3-6	7.5YR 3/2		Silt Loam	29	53	18	16			3F		Typic Aquiturbel - post fire
		Bg/Bwjj	6-42	5Y 4/1		Loam	31	49	21	22			3F, 1M		
		Bg/Bgjj	42-90	5Y 4/1		Silt Loam	28	55	18	14					
		Cg	90-120	5Y 4/1		Loam	30	49	22	28					
	04-02L	A BD					na	na	na		1.2327	0.5420		Shoulder	Ruptic-Histic Aquorthel
	8/27/2012	A	0-20	7.5YR 3/2		Silt Loam	na	na	na	1					Typic Aquiturbel - post fire
		Ajj	0-30	7.5YR 3/2		Silt Loam	15	70	16	5					
		Bg	20-40	5Y 4/1	F3M MAT 7.5YR 4/6	Silt Loam	31	54	16	12					
		Oejj	20-60	10YR 2/2		Sandy Loam	57	30	13	2			2F		
		Oajj	60-80	7.5YR 2.5/1		Silt Loam	18	69	14	38			2F		
4	04-03	Oi BD	0-22	7.5YR 5/4			na	na	na	14	0.2711	0.0570	4F	Backslope	Ruptic-Histic Aquorthel
	8/27/2012	Oi2 BD	22-30	7.5YR 4/3			na	na	na	0	0.4958	0.1226	4F, 3M, 1C		
		A	30-35	7.5YR 3/3		Sandy Loam	53	36	12	0			3F, 1M		
		Bg	35-55	5Y 4/1		Loam	42	43	16	3			3F		
		Oajj	55-60	5YR 2.5/1			na	na	na	0					
		Bg/Oajj	60-70	5Y 4/1			ns	ns	ns	5					
		Cgf	70-80	5Y 4/1		Loam	37	46	18	6					
4	04-04	Oa BD	0-12	5YR 2.5/1			na	na	na	1	0.5698	0.1759	4F	Footslope	Histic Cryaquept
	8/27/2012	Bg	12-20	5Y 4/1	F2M PL 4N	Loam	42	47	12	50			4F, 2M		Typic Cryaquept
		Ab	20-30	10YR 2/1		Loam	42	46	12	56			3F, 1M		
		Bgb	30-47	5Y 4/1	F3M MAT 10YR 5/3	Loam	50	38	11	65			3F		
		Cg	47-60	N 4	F3M PL 7.5YR 4/4	Sandy Loam	54	35	11	62			3F		

Transect	Site & Date	Horizon	Depth	Munsell Color	Redoximorphic Features	Texture	Sand	Silt	Clay	Rock Fragment (>2mm)	Moist Bulk density	Dry Bulk density	Roots [1]	Slope position	Taxonomy
			cm	(moist)			%	%	%	%	Mg m-3	Mg m-3			
5	05-01	Oi BD	0-20	7.5YR 4/4			na	na	na	1	1.2067	0.1946	5F, 1M	Broad Saddle	Ruptic Histoturbel
	8/28/2012	Oe BD	30-37	7.5YR 2.5/2			na	na	na	0	0.7893	0.1550	2F, 1M		
		Bw BD					na	na	na	19	2.0553	1.7180			
		Bw	37-50	10YR 5/2		Loam	41	44	14	9			2F		
		Cg/Oajj	50-80	2.5Y 5/2		Sandy Loam	68	27	5	13					
	05-02	Oi BD	0-8	7.5YR 2.5/1.5			na	na	na	7	0.4876	0.0939	4F, 1M	Shoulder	Typic Histoturbel
	8/28/2012	Oe BD	8-16	7.5YR 3/2			na	na	na	1	0.7667	0.1045	4F, 1M		
		Oa BD	16-22	7.5YR 2.5/1			na	na	na	1	1.3696	0.2104	3F		
		O'e BD	22-32	7.5YR 3/3			na	na	na	0	1.1570	0.3492	3F		
		Bg BD					na	na	na	16	2.0070	1.6193			
		Bg	32-48	2.5Y 3.5/1		Loam	42	49	10	16			1F		
		Cgf	48-80	5Y 4/1		Sandy Loam	62	30	8	9					
5	05-03 R	Oi	0-8	7.5YR 3/3			na	na	na	10			4F, 2M	Backslope	Ruptic Histoturbel
	8/28/2012	Bg1	8-15	2.5Y 4/2		Loam	40	47	14	17			4F, 1M		
		Bg/Ajj	15-50	2.5Y 4/2	F2M MAT2.5Y 4/1 F3M MAT 10YR 4/4 F3M PL 7.5YR 4/4	Silt Loam	31	55	15	67			2F, 2M		
		Ajj	25-40	7.5YR 2.5/1		Silt Loam	36	54	10	1			4F		
		Oajj	50-55	7.5YR 3/1		Loam	42	48	10	12			1F		
		Bg2	55-70	5Y 4/1		Loam	32	49	19	39					
		Cg/Ajjf	70-100	2.5Y 4/2	F3M MAT 7.5YR 6/6	Loam	48	41	12	59					
	05-03 L	Oi	42-50	7.5YR 3/3			na	na	na	6				Backslope	Ruptic Histoturbel
		Oe BD	50-65	7.5YR 2.5/2			na	na	na	3	0.7786	0.1015			
		Oa BD	65-70	7.5YR 2.5/1			na	na	na	0	1.1986	0.4931			
	05-03 C	Oaf	70-80	7.5YR 2.5/1			na	na	na	3				Backslope	Ruptic Histoturbel

Transect	Site & Date	Horizon	Depth	Munsell Color	Redoximorphic Features	Texture	Sand	Silt	Clay	Rock Fragment (>2mm)	Moist Bulk Density	Dry Bulk Density	Roots [1]	Slope position	Taxonomy
			cm	(moist)			%	%	%	%	Mg m-3	Mg m-3			
	05-04	Oi BD	0-12	7.5YR 3/3			na	na	na	9	0.3427	0.0977	5F, 4M	Backslope	Typic Historthel
	8/28/2012	Oa BD	12-18	7.5YR 2.5/1			na	na	na	1	1.0182	0.2807	5F, 4M		
		Oa	18-20	10YR 3/3			na	na	na				3F, 1M		
		Bw	20-38	10YR 5/3		Loam	46	42	12	69					
		Bg1	38-41	5Y 5/1	F2M PL 2.5Y 4/1 F3M MAT 7.5YR 4/6	Loam	50	38	13	5					
		Bg2 BD					na	na	na	5	2.0750	1.6447			
		Bg2	41-60	5Y 4/1		Loam	46	41	13	32					
		Cf	60-80	2.5Y 4/2		Loam	48	39	14	25					
6	06-01	Oi BD	0-35	7.5YR 5/4			na	na	na	11	0.2880	0.0862	4F	Shoulder	Typic Historthel
	8/29/2012	Oe BD	35-38	7.5YR 3/2			na	na	na	0	0.6709	0.2372	4F, 3M, 1C		
		Bw	38-42	10YR 4/2.5		Loam	42	40	18	74			3F, 1M		
		Bg	42-53	5Y 5/1	F3M PL 10YR 5/3 F2M MAT 2.5Y 5/3	Silt Loam	31	51	18	55			1F		
		Cgf	53-80	5Y 5/1	F2M PL 5Y 4/1 F3M MAT 7.5YR 5/4	Loam	39	46	16	59					
6	06-02	Oi	0-8	7.5YR 5/3			na	na	na	0			4F, 2M, 1C	Backslope	Typic Aquiturbel
	8/29/2012	O\A	8-15	10YR 3/1		Silt Loam	28	57	15	0			4F, 1M		
		Bw	16-35	10YR 4/3		Silt Loam	33	56	11	9			2F, 1M		
		Bg/Bw	35-51	2.5Y 4/1		Silt Loam	39	51	11	11			1F		
		Bw/Ajj	51-70	2.5Y 5/3	F3M MAT 7.5YR 4/6	Silt Loam	34	54	12	10					
		Bg	70-82	5Y 4/1	F3M MAT 2.5YR 4/4	Silt Loam	34	53	14	11					
		Cgf	82-100	2.5Y 4/1.5		Loam	44	42	14	55					

Transect	Site & Date	Horizon	Depth	Munsell Color	Redoximorphic Features	Texture	Sand	Silt	Clay	Rock Fragment (>2mm)	Moist Bulk Density	Dry Bulk Density	Roots [1]	Slope position	Taxonomy
			cm	(moist)			%	%	%	%	Mg m-3	Mg m-3			
6	06-03	Oi	0-9	7.5YR 5/4			na	na	na	4			4F, 2M	Backslope	Typic Hitoturbel
	8/29/2012	Oe BD	9-17	2.5YR 2.5/1			na	na	na	13	0.3704	0.1376	4F, 2M, 1C		
		Oa	17-22	2.5YR 2.5/1			na	na	na	2			3F, 2M		
		A	22-26	10YR 3/1		Silt Loam	30	58	12	38			4F, 1M		
		Bg/Oajj L	26-50	2.5Y 3.5/2	F3M PL 5YR 4/6	Loam	42	42	16	60			2F		
		Bg/Oajj R	26-75	2.5Y 4/1	F3M MAT 5YR 4/4	Loam	42	40	18	44			1M		
		Cgf	75-100	5Y 4/1		Loam	34	46	20	69			3F		
7	07-01	Oi BD	0-11	7.5YR 4/3			na	na	na	3	0.5574	0.1459	4F	Shoulder	Typic Aquiturbel
	8/30/2012	Oa BD					na	na	na	5	1.3510	0.5627			
		Oa	11-18	7.5YR 2.5/1			na	na	na	6			4F, 2M		
		A BD					na	na	na	22	1.8200	1.3743			
		A	18-25	7.5YR 3/2		Sandy Loam	52	38	10	21			3F, 2M		
		Bg BD					na	na	na	6	2.1677	1.7753			
		Bg	25-38	5Y 4/1		Silt Loam	23	61	16	14			2F		
		Bg/Ajj BD					na	na	na	6					
		Bg/Ajj	38-70	5Y 4/1		Silt Loam	28	56	16	13					
		Bg/Ajjf	70-80	5Y 4/1		Silt Loam	38	50	12	8					
		Cf	80-100	5Y 4/1		Silt Loam	19	69	13	6					
7	07-02 R	Oi BD	0-30	7.5YR 4/2			na	na	na	6	0.2740	0.0920		Middle Backslope	Ruptic-Histic Aquiturbel
	8/30/2012	Oe BD	30-40	7.5YR 3/1			na	na	na	0	0.6285	0.1521			
		Bgf	40-60	5Y 4/1	F3M PF 7.5YR 4/6	Silt Loam	23	59	18	8					
		Cgf	60-100	10YR 3/1.5		Silt Loam	22	72	7	31					

Transect	Site & Date	Horizon	Depth	Munsell Color	Redoximorphic Features	Texture	Sand	Silt	Clay	Rock Fragment (>2mm)	Moist Bulk density	Dry Bulk density	Roots [1]	Slope position	Taxonomy
			cm	(moist)			%	%	%	%	Mg m-3	Mg m-3			
	07-02 L	Oi BD	0-8	7.5YR 4/2			na	na	na	6	0.2128	0.0899	3F, 3M, 1C	Middle Backslope	Ruptic-Histic Aquiturbel
	8/30/2012	Oa BD					na	na	na	1	0.7960	0.5290			
		Oa	8-48	5YR 4/1			na	na	na	3			3F, 2M		
		Bg/Ajj BD					na	na	na	0	1.8733	1.4107			
		Bg/Ajj	48-73	5Y 4/1	F3M MAT 10YR 4/4 F3M PL 7.5YR 4/4 F3M PF 10YR	Silt Loam	26	61	14	18			2F, 1M		
	Inclusion	Bgjj BD Incl.					na	na	na	15	2.1110	1.7163			
	Inclusion	Bgjj Incl.	20-65	5Y 4/1		Silt Loam	18	62	20	15					
	07-03	Oi BD	0-9	7.5YR 3/3			na	na	na	4	0.2483	0.1222	3F, 2M	Toe slope	Burned- Typic Aquiturbel
	8/30/2012	Oe	9-20	7.5YR 2.5/2									3F, 2M		
		A BD					na	na	na	12	1.5653	1.1227			
		A	10-20	10YR 3/2		Silt Loam	33	51	16	19			4F, 3M	Footslope	Aquic Humicryept - Post fire
		Bw1 BD					na	na	na	17	2.2647	1.9147			
		Bw1	20-38	10YR 4/3	F2M PL 2.5Y 4/1 F3M MAT 7.5YR 4/4 F3M MAT	Loam	39	44	18	28			1F		
		Ajj BD					na	na	na	27	1.0147	1.7143	2F		
		Ajj	38-42	10YR 3/1		Loam	37	46	17	27					
		Bw2	42-65	10YR 4/3	F3M MAT 7.5YR 4/6 F2M 5Y 4/1	Loam	37	41	22	46					
		2C	65-115	5Y 3/1		Silt Loam	73	22	5	1					
8	08-01	A BD	0-10	7.5YR 2.5/2		Silt Loam	33	52	14	1	0.2729	0.1249	4F, 2M, 1C	Upper Backslope	Typic Cryaquept
	8/31/2012	Bw1 + A BD					na	na	na		2.2677	1.4607			
		Bw1	10-18	10YR 5/4		Loam	43	43	14				4F, 1M, 1C		
		A	18-20	10YR 3/3		Silt Loam	23	59	18				4F, 1M, 1C		
		Bw2 BD					na	na	na	20	1.7337	1.1927			
		Bw2	20-40	10YR 4/4		Silt Loam	17	66	16	21			2F		
		Bg	40-75	2.5Y 4.5/2	F3M MAT 7.5YR 4/4 F3M PL 5YR 4/6	Silt Loam	12	76	12	70			1F		

Transect	Site & Date	Horizon	Depth	Munsell Color	Redoximorphic Features	Texture	Sand	Silt	Clay	Rock Fragment (>2mm)	Moist Bulk density	Dry Bulk density	Roots [1]	Slope position	Taxonomy
			cm	(moist)			%	%	%	%	Mg m-3	Mg m-3			
8	08-02	Oi BD	0-10	5YR 3/2			na	na	na	7	0.2722	0.0801	5F. 3M	Upper Backslope	Typic Cryaquept
	8/31/2012	Oe BD	10-15	5YR 3/2			na	na	na	3	0.5864	0.2128	4F, 2M		
		A	15-18	10YR 3/3		Loam	46	40	15	16			3F		
		Bw	18-50	10YR 5/3		Loam	44	39	17	85			2F		
		Bg	50-100	2.5Y 5.5/2	F3M PL 7.5YR 4/4	Sandy Loam	61	15	24	57					
	08-03 R	Oi BD	0-15	7.5YR 4/3			na	na	na	3	0.0851	0.0350		Upper Backslope	Lithic Dystrocryept
	8/31/2012	Bw	15-55	10YR 5/3		Silt Loam	18	67	15	82			2F, 1M		
		Bc	55-80	2.5Y 5/2		Loam	38	46	16	72					
	08-03 L	Oi BD	0-10	7.5YR 4/3			na	na	na	6	0.3110	0.0878	3F, 3M, 1C	Upper Backslope	Lithic Dystrocryept
	8/31/2012	Oe	10-16	5YR 2.2/2			na	na	na	4			4F, 2M		
		A BD					na	na	na		1.1233	0.7337			
		A	16-20	10YR 4/3		Loam	44	44	12	1			4F, 2M		
	08-04	Oi BD	0-10	5YR 3/1			na	na	na	12			5F, 4M, 2C	Upper Backslope	Histic Cryaquept
	8/31/2012	Oe BD	10-18	7.5YR 2.5/1			na	na	na	5			4F, 3M, 1C		
		Oa BD					na	na	na	0	1.3167	0.5530			
		Oa	18-26	10YR 3/2.5			na	na	na	0			3F		
		Bw	26-50	10YR 4/3		Sandy Loam	62	19	19	81			2F		
		Bg	50-105	2.5Y 4/2	F3M MAT 10YR 5/4 F3M PL 10YR 5/4	Loam	34	47	19	45					

Transect	Site & Date	Horizon	Depth	Munsell Color	Redoximorphic Features	Texture	Sand	Silt	Clay	Rock Fragment (>2mm)	Moist Bulk density	Dry Bulk density	Roots [1]	Slope position	Taxonomy
			cm	(moist)			%	%	%	%	Mg m-3	Mg m-3			
9	09-01	Oi BD	0-4	7.5YR 3/3			na	na	na	7	0.3777	0.1697	2F, 3M	Middle backslope	Ruptic-Histic Aquiturbel
	9/1/2012	A	4-7	7.5YR 3/2		Silt Loam	31	54	15	13			4F		Aquic Dystrocryept
		Bw/Bg BD					na	na	na	8	2.0860	1.6953			
		Bw/Bg	7-30	10YR 4/2	F2M PL 2.5Y 4/1 F3M MAT 7.5Y 4/4	Silt Loam	24	60	16	13			2F, 1M		
		Bg/Ajj BD					na	na	na	11	1.0323	1.6613			
		Bg/Ajj	30-48	10YR 4/2		Silt Loam	17	66	17	5			2F		
		Bg BD					na	na	na	26	2.0547	1.7323			
		Bg	48-59	10YR 4/2.5		Silt Loam	15	64	21	25					
		2C	59-80	2.5Y 4/2		Loam	37	38	25	76					
9	09-02	Bw1	1-7	5YR 5/4		Silt Loam	9	72	19	5			2F. 2M	Lower Backslope	Lithic Haplocryept
	9/1/2012	Bw2	7-15	7.5YR 4/4		Silt Loam	1	80	19	1			1F		
		2Cr	15-50	7.5YR 6/6			na	na	na	80					
	09-03	Oi BD	0-7	5YR 2.5/2			na	na	na	8	0.3139	0.1293	4F	Terrace-	Typic Cryaquept
	9/1/2012	Oi BD					na	na	na	0	1.9640	1.5940		Footslope	
`=		Bw/Ajj BD					na	na	na	1	1.9620	1.5487			
		Bw/Ajj	7-35	10YR 4/3		Silt Loam	4	80	15	0			4F, 1M		
		Bg1 BD	35-50	10YR 3.5/2	F3M PL 7.5YR 4/4	Silt Loam	14	77	9	1	1.7433	1.3567	1F		
		Bg1	35-50				na	na	na	0					
		Bg2 BD	50-82	10YR 4/2	F3M MAT 10YR 4/4	Silt	4	84	12	1					
		Cf	82-100	10YR 4/2	F2M PL 2.5Y 4/1 F3M PL 7.5YR 4/4	Silt	6	82	13	0					

Transect	Site & Date	Horizon	Depth	Munsell Color	Redoximorphic Features	Texture	Sand	Silt	Clay	Rock Fragment (>2mm)	Moist Bulk density	Dry Bulk density	Roots [1]	Slope position	Taxonomy
			cm	(moist)			%	%	%	%	Mg m-3	Mg m-3			
10	10-01	A	0-3	7.5YR 4/3		Loam	40	43	17	55			2F, 3M, 1C	Summit	Lithic Dystrocryept
	9/2/2012	Bw	3-8	7.5YR 4/4		Loam	47	41	12	54			2F, 1M, 1C		
		BC	8-25	7.5YR 6/5		Loam	ns	ns	ns	68					
		CR	25-50			Loam	na	na	na	95					
	10-02	Oi BD	0-16	7.5YR 3/2			na	na	na	13	0.3262	0.1162	5F	Backslope	Typic Historthel
	9/2/2012	Oa BD	16-30	5YR 3/2			na	na	na	0	1.1104	0.3628	3F, 3M, 1C		
		A	30-38	10YR 3/2		Silt Loam	19	69	12	12			4F		
		Bg1	38-47	5YR 4/1	FEM MAT 7.5 YR 4/6 F3M PL 10YR 4/3	Silt Loam	12	71	18	48			4F		
		Bg2 Red	47-55	7.5YR 4/6		Silt Loam	8	70	22	32			1F		
		Bg2 Grey	47-55	2.5Y 4/1		Silt Loam	14	70	17	28					
		BC	55-70	2.5Y 3/1	F3M MAT 7.5YR 4/6	Silt Loam	12	72	16	29					
		Ab/Cf	70-85	10YR 2.5/2		Silt Loam	12	74	15	36					
		Cf	85 - 100	2.5Y 4/1		Silt Loam	12	71	18	14					
10	10-03	Oi BD	0 -10	7.5YR 4/3			na	na	na	3	0.3001	0.0696	4F,4M	Footslope	Typic Historthel
	9/2/2012	Oe BD	10 18	5YR 2.5/1			na	na	na	5	0.3799	0.1286	4F, 3M, 1C		
		Oa BD					na	na	na			0.5107			
		Oa	18 - 22	7.5YR 2.5/1			na	na	na				4F, 2M		
		A	22 - 32	7.5YR 3/1		Silt Loam	22	66	12				3F, 2M		
		Bg	32 - 38	2.5Y 3/2	F3M PL 7.5YR 4/6 F3M PF 7.5YR 4/4 F2M PL 5Y 4/1	Loam	32	49	20	6			2F		
		Ab/C	38 - 50	10YR 2/1		Silt Loam	24	62	14	35					
		Cf	50- 80			Silt Loam	na	na	na	30					

1. Roots - Codes 1 to 5 for number of roots

APPENDIX D. Soil Chemical Properties of the toposequence study sites in the Steese and White Mountains area, Alaska

Site & Date	Horizon	Depth	pH	E.C.	C Loss on Ignition	Inorganic Carbon	Total C (LECO)	N	C: N Ratio	OM Carbon	P	CEC	K	Ca	Mg	Na[1]	Base Saturation
		cm		dS/m	%	%	%	%		%	ppm	cmols/kg					%
01-01	A	0-5	4.24	0.10	12.68	0.00	8.25	0.37	22.30	65	4	18.64	0.27	2.77	0.72	0.02	20.27
8/24/2012	Bw1	5-11	4.39	0.04	6.06	0.00	2.77	0.19	14.53	46	1	11.79	0.09	0.26	0.13	0.03	4.30
	Bw2	11-18	4.82	0.09	2.36	0.00	0.82	0.07	12.45	35	<1	7.76	0.06	0.32	0.13	0.04	6.98
	Bw3	15-35	4.63	0.10	2.59	na[2]	1.01	0.01	70.81	39	1	7.00	0.06	0.50	0.19	0.03	11.31
	Cr	35-50															
01-02	Oi BD		3.76	0.16	80.00		49.82	1.55	32.17	62	93	81.47	1.26	26.89	3.32	0.08	38.73
8/24/2012	Oi	0-5	4.15	0.19	90.72	na	54.40	1.65	33.02	60	97	90.33	1.26	27.64	3.97	0.11	36.51
	Oe	5-10	4.18	0.10	73.36	na	47.19	1.89	24.94	64	37	59.62	0.48	21.01	2.66	0.08	40.65
	Oa	10-15	4.14	0.09	49.60	na	30.14	1.23	24.42	61	1	46.47	0.23	7.91	1.10	0.09	20.07
	Oa BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Bw	15-25	4.45	0.22	15.87	na	9.34	0.42	22.34	59	<1	33.28	0.08	5.26	0.55	0.05	17.84
	Bw BD		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	Bg	15-25	3.90	0.14	4.42	na	2.22	0.11	20.33	50	<1	21.10	0.05	1.79	0.29	0.04	10.24
	Cr	25-35															
01-03	Oi Bd	0-9	3.99	0.18	94.19	na	51.40	1.28	40.08	55	103	94.29	2.01	32.52	6.76	0.00	43.79
8/24/2012	Oa Bd		na	na	na	na	na	na			na	na	na	na	na	na	na
	Oa	9-23	4.37	0.09	75.84	na	43.53	2.26	19.30	57	11	61.62	0.47	32.89	4.00	0.08	60.77
	Bg1 BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Bg1	23-38	5.01	0.11	3.92	na	2.09	0.12	16.77	53	<1	10.15	0.07	6.20	1.80	0.04	79.83
	Bg2 BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Bg2	38-52	5.40	0.11	7.28	na	4.08	0.20	20.70	56	2	17.07	0.18	9.94	1.73	0.06	69.73
	Cg/Oajjf	52-80	5.22	0.16	9.18	na	5.06	0.34	15.02	55	1	20.68	0.24	12.35	1.57	0.05	68.75

Site & Date	Horizon	Depth	pH	E.C.	C Loss on Ignition	Inorganic Carbon	Total C (LECO)	N	C: N Ratio	OM Carbon	P	CEC	K	Ca	Mg	Na[1]	Base Saturation
		cm		dS/m	%	%	%	%		%	ppm	cmols/kg	cmols/kg				%
01-04	Oi BD	0-12	3.68	0.23	92.78	na	53.65	1.23	43.56	58	48	75.36	3.01	10.95	4.54	0.00	24.54
8/24/2012	Oe BD	12-18	4.17	0.17	90.42	na	50.16	1.40	35.88	55	28	88.23	1.36	22.68	4.24	0.00	32.05
	Bw1	18-25	4.09	0.12	5.88	na	2.82	0.12	22.72	48	4	13.97	0.05	2.52	0.59	0.02	22.77
	Bw2	25-32	4.50	0.06	2.92	na	1.42	0.06	22.36	48	<1	7.66	0.02	1.06	0.25	0.02	17.56
	Bg	32-38	4.47	0.07	3.26	na	1.55	0.05	29.44	48	5	10.37	0.03	0.90	0.24	0.03	11.64
	Cf/Wf	38-80	4.72	0.07	4.47	na	2.28	0.10	21.88	51	<1	9.65	0.04	1.16	0.24	0.03	15.33
02-01	Oi	0-12	4.09	0.19	91.95	na	53.77	1.43	37.63	58	86	62.37	0.74	9.26	3.38	0.01	21.47
8/25/2012	Oa	12-28	3.99	0.17	65.75	na	36.37	1.27	28.71	55	17	70.85	1.07	9.61	4.01	0.02	20.76
	Bw	28-40	4.12	0.06	2.55	na	1.00	0.02	65.35	39	<1	7.56	0.06	0.58	0.50	0.02	15.50
	A	0-5	4.11	0.12	6.32	na	3.05	0.14	21.09	48	7	10.14	0.26	2.54	1.33	0.01	40.93
	Bw1	5-18	4.56	0.06	1.38	na	0.41	0.01	38.34	30	<1	5.67	0.04	0.62	0.38	0.03	18.89
	Bw2	18-42	4.41	0.05	1.56	na	0.50	0.02	22.00	32	<1	6.82	0.04	0.54	0.35	0.03	14.16
	BC	42-80	4.53	0.04	2.09	na	0.68	0.04	16.41	33	<1	7.65	0.05	0.75	0.43	0.02	16.40
02-02	Oi BD	0-14	3.73	0.24	92.20	na	53.24	1.52	34.98	58	54	76.51	2.35	13.26	6.43	0.00	28.80
8/25/2012	Oa Bd		na	na	na	na	na	na			na	na	na	na	na	na	na
	Oa	14-23	3.83	0.12	61.69	na	36.98	1.58	23.38	60	5	79.44	0.38	6.40	2.18	0.14	11.45
	A BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	A	23-30	4.06	0.06	40.31	na	23.32	0.92	25.27	58	2	47.07	0.11	3.11	1.20	0.10	9.60
	Bw/Ajj BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Bw/Ajj	30-48	4.32	0.04	11.40	na	6.42	0.28	23.10	56	<1	21.73	0.05	1.45	0.60	0.06	9.92
	A/BwjjF	48-58	4.25	0.07	14.39	na	8.04	0.36	22.32	56	<1	21.61	0.08	1.56	0.62	0.05	10.65
	Crf	58-80															
02-03	Oi1	0-36	3.82	0.08	98.00	na	52.21	0.94	55.38	53	40	98.62	1.95	13.02	5.25	0.00	20.51
8/25/2012	Oi2	26-44	3.73	0.11	94.15	na	51.36	2.01	25.50	55	56	101.07	0.79	16.47	5.05	0.14	22.22
	Oaf	44-60	3.84	0.12	64.01	na	36.60	1.86	19.71	57	4	95.24	0.28	14.64	4.25	0.21	20.34
	Cf																

Site & Date	Horizon	Depth	pH	E.C.	C Loss on Ignition	Inorganic Carbon	Total C (LECO)	N	C: N Ratio	OM Carbon	P	CEC	K	Ca	Mg	Na[1]	Base Saturation
		cm		dS/m	%	%	%	%		%	ppm	cmols/kg					%
02-04	Oi	0-5	3.65	0.50	83.30	na	48.72	2.05	23.79	58	120	71.16	3.16	8.72	3.06	0.00	20.99
8/25/2012	Oa	5-8	3.66	0.18	46.27	na	29.27	1.15	25.41	63	15	64.78	0.75	4.30	1.41	0.11	10.15
	Bw	5-25	4.02	0.10	16.03	na	9.67	0.41	23.67	60	1	34.36	0.30	2.37	0.94	0.08	10.74
	Ab	25-33	3.92	0.10	6.84	na	3.16	0.17	18.35	46	2	15.41	0.11	1.11	0.47	0.04	11.22
	Bwb	33-55	3.93	0.08	2.94	na	1.19	0.03	38.21	40	2	8.07	0.06	0.70	0.32	0.03	13.71
03-01	Oi BD	0-8	4.33	0.16	94.95	na	52.15	1.15	45.23	55	52	73.40	1.93	48.30	6.20	0.00	76.87
8/26/2012	Oa BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Oa	8-15	5.05	0.32	47.21	na	26.54	1.41	18.83	56	10	77.05	0.48	60.98	4.02	0.00	84.99
	A BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	A	15-21	5.31	0.20	31.27	na	17.70	1.16	15.28	57	3	67.30	0.17	52.15	2.85	0.01	81.99
	Oejj	21-25	5.47	0.17	49.69	na	29.26	1.76	16.67	59	4	101.45	0.15	81.54	3.75	0.04	84.26
	Bw	25-40	5.61	0.10	3.21	na	1.31	0.11	12.01	41	2	14.55	0.07	9.89	0.62	0.01	72.72
	Bg	40-60	5.93	0.11	1.66	na	0.60	0.05	10.86	36	1	7.23	0.04	6.98	0.31	0.00	100
03-02	Oi BD	0-8	3.88	0.22	93.92	na	53.20	1.25	42.46	57	119	66.99	2.04	21.78	5.04	0.04	43.14
8/26/2012	Oe BD	8-13	3.95	0.09	95.39	na	53.51	1.43	37.34	56	37	72.35	1.56	25.89	3.48	0.00	42.75
	A BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	A	13-22	4.74	0.11	26.28	na	15.36	0.90	17.14	58	1	113.43	0.37	63.83	3.59	0.08	59.83
	Bg/Oajj BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Bg/Oajj	22-46	5.06	0.06	7.23	na	3.94	0.26	15.20	55	<1	18.37	0.05	11.10	0.84	0.04	65.46
	Ajj BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Ajj	22-30	5.20	0.14	19.27	na	10.40	0.62	16.84	54	1	48.23	0.16	32.14	2.34	0.05	71.92
	Bg/Oajj	30-46	4.93	0.07	21.42	na	12.04	0.66	18.20	56	<1	48.40	0.12	23.26	1.33	0.02	51.08
	Cgf	46-80	5.36	0.08	4.03	na	2.15	0.13	15.96	53	<1	9.32	0.09	6.93	0.45	0.01	80.36

Site & Date	Horizon	Depth	pH	E.C.	C Loss on	Inorganic Carbon	Total C (LECO)	N	C: N Ratio	OM Carbon	P	CEC	K	Ca	Mg	Na[1]	Base Saturation
		cm		dS/m	%	%	%	%		%	ppm	cmols/kg	cmols/kg				%
03-03R	Oi BD	0-8	3.46	0.34	89.86	na	52.37	1.02	51.28	58	43	73.57	2.09	10.95	6.53	0.05	26.68
8/26/2012	Oe BD	8-18	3.50	0.14	46.67	na	27.59	1.13	24.43	59	4	68.34	0.66	1.73	1.89	0.02	6.29
	Bw1	18-75	4.82	0.12	2.96	na	1.31	0.09	14.88	44	<1	12.05	0.11	5.38	1.49	0.03	58.24
	Bw2	75-80	4.86	0.06	1.60	na	0.68	0.41	1.67	43	<1	9.14	0.07	3.86	1.20	0.03	56.41
03-03L	Oi BD	0-20	3.74	0.10	97.39	na	51.22	0.61	84.16	53	26	102.76	1.15	14.10	5.96	0.00	20.63
8/26/2012	Oajj BD		4.70	0.12	89.92	na	50.59	1.57	32.14	56	45	94.91	0.87	52.58	9.13	0.06	65.99
	Oajj	20-60	4.31	0.19	72.59	na	42.87	1.57	27.39	59	9	94.96	0.47	33.72	6.06	0.06	42.44
	Cgf	60-80	4.92	0.12	24.10	na	12.23	0.77	15.85	51	2	47.76	0.16	21.22	4.26	0.04	53.76
04-01	A	0-5	4.49	0.11	8.35	na	4.97	0.33	14.92	60	10	15.54	0.31	3.06	0.98	0.01	28.02
8/27/2012	Bw1	5-20	4.39	0.07	3.47	na	1.93	0.15	13.17	56	1	11.28	0.10	0.19	0.26	0.00	4.95
	Bw2	20-35	4.96	0.04	3.79	na	1.17	0.06	17.98	31	<1	9.20	0.09	0.16	0.15	0.02	4.53
	BC	35-55	4.74	0.04	1.23	na	0.37	0.02	19.80	30	1	5.66	0.05	0.71	0.55	0.01	23.11
	Cf																
04-02R	Oe	0-3	4.76	0.19	53.20	na	30.65	0.91	33.63	58	89	56.48	1.25	28.74	6.00	0.00	63.72
8/27/2012	A	3-6	4.57	0.08	10.06	na	5.23	0.11	49.79	52	1	17.75	0.23	6.69	2.05	0.03	50.66
	Bg/Bwjj	6-42	5.19	0.05	1.93	na	1.01	0.06	15.67	52	4	9.05	0.09	4.94	1.64	0.06	74.26
	Bgjj	42-50	4.99	0.06	3.32	na	1.71	0.01	150.71	51	<1	10.06	0.07	3.39	0.94	0.06	44.47
	Cg	50-120	6.69	0.20	1.67	na	0.68	0.02	37.98	41	4	8.64	0.12	8.61	1.22	0.03	100
04-02L	A BD		na	na	na	na	na	na			na	na	na	na	na	na	na
8/27/2012	A	0-20	5.10	0.19	68.26	na	40.00	1.70	23.50	59	6	62.48	0.47	19.79	4.64	0.09	40.00
	Ajj	0-30	6.04	0.15	7.67	na	3.84	0.27	14.30	50	4	22.93	0.15	21.45	1.89	0.04	100
	Bg	20-40	4.82	0.06	4.00	na	2.09	0.06	33.46	52	<1	9.55	0.04	2.18	0.65	0.02	30.33
	Oejj	20-60	5.07	0.14	49.15	na	29.08	1.29	22.55	59	2	51.42	0.24	19.03	4.31	0.07	46.01
	Oajj	60-80	5.81	0.14	12.32	na	6.97	0.50	13.92	57	2	31.86	0.12	26.25	2.40	0.04	90.44
04-03	Oi BD	0-22	3.84	0.13	95.96	na	51.63	1.10	46.74	54	78	94.82	1.44	12.84	7.02	0.00	22.47
8/27/2012	Oi2 BD	22-30	4.26	0.20	74.10	na	40.38	1.55	26.11	54	3	83.36	0.34	25.15	5.94	0.07	37.79
	A	30-35	4.14	0.27	42.79	na	23.90	1.00	24.00	56	2	57.60	0.18	13.01	2.95	0.10	28.20
	Bg	35-55	4.35	0.14	4.21	na	2.25	0.08	27.22	53	<1	10.80	0.05	1.77	0.80	0.02	24.56
	Oajj	55-60	4.68	0.29	50.23	na	29.44	1.21	24.39	59	<1	52.66	0.08	10.73	2.44	0.05	25.26
	Bg/Oajj	60-70	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
	Cgf	70-80	4.45	0.25	4.08	na	2.10	0.04	54.96	52	7	10.87	0.12	3.00	0.90	0.04	37.34

Site & Date	Horizon	Depth	pH	E.C.	C Loss on Ignition	Inorganic Carbon	Total C (LECO)	N	C: N Ratio	OM Carbon	P	CEC	K	Ca	Mg	Na[1]	Base Saturation
		cm		dS/m	%	%	%	%		%	ppm	cmols/kg	cmols/kg				%
04-04	Oa BD	0-12	4.65	0.15	75.25	na	43.22	1.91	22.63	57	3	75.42	0.65	15.47	4.60	0.15	27.68
8/27/2012	Bg	12-20	4.52	0.06	6.83	na	4.08	0.19	21.68	60	<1	15.30	0.06	2.58	0.85	0.02	22.93
	Ab	20-30	4.43	0.07	6.95	na	3.98	0.17	23.51	57	<1	14.97	0.07	2.56	0.81	0.06	23.35
	Bgb	30-47	4.45	0.07	2.81	na	1.23	0.06	20.85	44	<1	9.62	0.08	2.22	0.75	0.03	31.96
	Cg	47-60	5.24	0.11	0.86	na	0.10	0.04	2.50	12	3	6.24	0.06	8.28	1.49	0.03	157.95
05-01	Oi BD	0-20	3.60	0.11	97.30	na	52.79	0.97	54.63	54	43	55.20	1.06	8.51	5.69	0.00	27.64
8/28/2012	Oe BD	30-37	3.77	0.11	92.65	na	52.09	1.92	27.15	56	19	87.95	0.90	8.75	4.24	0.06	15.85
	Bw BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Bw	37-50	4.52	0.06	6.07	na	3.83	0.15	25.27	63	<1	9.15	0.05	1.16	0.76	0.03	21.87
	Cg/Oajj	50-80	4.81	0.11	29.32	na	18.51	0.86	21.54	63	<1	32.27	0.09	2.91	1.54	0.04	14.22
05-02	Oi BD	0-8	4.29	0.18	95.13	na	53.94	1.16	46.44	57	107	80.46	2.10	18.59	8.84	0.00	36.70
8/28/2012	Oe BD	8-16	4.41	0.08	94.67	na	50.52	1.28	39.57	53	1	83.79	1.18	18.08	7.96	0.00	32.49
	Oa BD	16-22	4.62	0.07	89.05	na	50.54	1.96	25.85	57	<1	102.58	0.39	18.69	6.33	0.00	24.78
	O'e BD	22-32	4.33	0.08	80.35	na	49.34	2.93	16.84	61	77	57.78	0.31	9.31	3.53	0.06	22.85
	Bg BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Bg	32-48	4.43	0.05	9.56	na	6.06	0.22	27.14	63	<1	13.99	0.04	2.00	0.85	0.02	20.77
	Cgf	48-80	4.51	0.08	23.19	na	13.20	0.56	23.60	57	<1	61.19	0.05	5.57	1.03	0.04	10.93
05-03 R	Oi	0-8	4.75	0.31	82.25	na	46.96	1.49	31.54	57	151	55.87	2.16	19.65	6.07	0.00	49.89
8/28/2012	Bg1	8-15	4.48	0.04	4.35	na	2.12	0.11	20.09	49	<1	8.75	0.03	0.74	0.21	0.02	11.43
	Bg/Ajj	15-50	4.63	0.05	4.40	na	2.21	0.13	17.58	50	<1	9.17	0.03	1.46	0.36	0.02	20.39
	Ajj	25-40	4.72	0.06	33.87	na	19.09	0.80	23.87	56	<1	44.91	0.06	6.05	1.21	0.05	16.42
	Oajj	50-55	4.85	0.07	15.46	na	9.31	0.48	19.51	60	<1	23.93	0.10	5.93	0.76	0.04	28.58
	Bg2	55-70	4.59	0.13	4.65	na	2.60	0.12	21.05	56	4	9.90	0.04	2.58	0.32	0.02	29.91
	Cg/Ajjf	70-100	4.60	0.06	6.80	na	3.72	0.17	21.54	55	<1	9.76	0.06	2.14	0.33	0.01	26.02
05-03 L	Oi	42-50	4.38	0.23	94.94	na	53.31	1.11	48.23	56	58	73.68	2.09	17.63	6.76	0.00	35.94
	Oe BD	50-65	4.91	0.13	89.66	na	50.52	1.67	30.32	56	7	90.01	0.76	19.53	6.75	0.04	30.09
	Oa BD	65-70	4.81	0.04	64.17	na	38.34	1.78	21.60	60	2	37.15	0.10	3.63	1.29	0.02	13.56
05-03 C	Oaf	70-80	4.61	0.17	37.79	na	21.13	1.00	21.09	56	1	44.13	0.12	7.15	2.19	0.00	21.45

Site & Date	Horizon	Depth	pH	E.C.	C Loss on Ignition	Inorganic Carbon	Total C (LECO)	N	C: N Ratio	OM Carbon	P	CEC	K	Ca	Mg	Na[1]	Base Saturation
		cm		dS/m	%	%	%	%		%	ppm	cmols/kg		cmols/kg			%
05-04	Oi BD	0-12	3.95	0.22	94.40	na	53.58	1.24	43.12	57	25	74.03	1.83	27.71	5.57	0.00	47.43
8/28/2012	Oa BD	12-18	4.25	0.12	68.05	na	40.11	1.70	23.53	59	7	69.11	0.51	23.21	3.98	0.02	40.10
	Oa	18-20	4.18	0.13	58.35	na	34.61	1.55	22.32	59	9	61.97	0.45	19.03	3.28	0.02	36.76
	Bw	20-38	4.08	0.06	2.58	na	1.16	0.05	23.00	45	<1	5.35	0.03	2.83	0.64	0.00	65.30
	Bg1	38-41	4.14	0.06	2.00	na	0.87	0.02	43.00	43	<1	6.57	0.02	1.68	0.40	0.00	31.90
	Bg2 BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Bg2	41-60	4.27	0.06	1.78	na	0.69	0.05	13.80	39	<1	4.93	0.04	1.88	0.38	0.00	46.73
	Cf	60-80	4.47	0.07	1.78	na	0.71	0.04	17.75	40	<1	5.26	0.06	2.09	0.55	0.01	51.59
06-01	Oi BD	0-35	3.47	0.12	97.38	na	53.96	1.25	43.18	55	21	97.98	1.27	7.67	3.33	0.00	12.52
8/29/2012	Oe BD	35-38	4.41	0.33	75.88	na	44.94	1.96	22.98	59	39	67.75	0.93	16.54	3.42	0.01	30.85
	Bw	38-42	4.17	0.10	3.58	na	1.73	0.09	19.95	48	4	10.40	0.04	2.63	0.66	0.01	32.15
	Bg	42.53	4.47	0.08	2.50	na	1.05	0.04	26.68	42	4	9.73	0.04	3.95	1.01	0.01	51.60
	Cgf	53-80	4.83	0.06	2.49	na	1.12	0.05	22.84	45	4	9.97	0.03	4.13	0.85	0.01	50.37
06-02	Oi	0-8	3.22	0.33	89.32	na	53.67	1.29	41.76	60	56	61.03	2.12	5.45	2.85	0.07	17.20
8/29/2012	O\A	8-15	3.42	0.14	24.16	na	13.49	0.55	24.56	56	5	40.69	0.36	2.31	0.93	0.05	8.97
	Bw	16-35	4.23	0.09	9.07	na	4.92	0.27	18.16	54	<1	19.39	0.08	5.21	1.08	0.02	32.89
	Bg/Bw	35-51	4.32	0.10	8.15	na	4.07	0.23	18.01	50	1	17.62	0.04	6.05	0.92	0.03	39.90
	Bw/Oajj	51-70	4.44	0.13	12.67	na	6.94	0.33	20.91	55	8	23.57	0.04	8.87	0.95	0.02	41.90
	Bg	70-82	4.57	0.06	4.22	na	2.24	0.08	26.79	53	4	11.88	0.04	4.32	0.76	0.01	43.21
	Cgf	82-100	4.32	0.14	3.87	na	2.03	0.09	22.81	53	15	8.39	0.03	3.39	0.47	0.02	46.56
06-03	Oi	0-9	3.93	0.38	92.80	na	56.33	1.17	47.98	61	27	77.61	2.31	42.20	4.36	0.11	63.12
8/29/2012	Oe BD	9-17	5.22	0.25	85.66	na	51.65	1.57	32.81	60	20	108.86	1.09	119.08	7.54	0.03	100
	Oa	17-22	5.42	0.19	42.12	na	25.86	1.05	24.65	61	4	95.86	0.21	91.80	5.07	0.07	100
	A	22-26	5.74	0.18	9.67	na	5.68	0.28	20.45	59	1	24.88	0.09	31.73	1.88	0.02	100
	Bg/Oajj L	26-50	5.38	0.09	2.98	na	1.40	0.06	22.09	47	<1	10.63	0.05	9.42	0.80	0.01	96.65
	Bg/Oajj R	50-75	5.54	0.10	2.37	na	1.02	0.03	40.12	43	<1	8.31	0.05	7.10	0.74	0.03	95.35
	Cgf	75-100	5.80	0.09	3.01	na	1.23	0.09	14.06	41	<1	9.14	0.05	9.27	0.98	0.03	100

Site & Date	Horizon	Depth	pH	E.C.	C Loss on Ignition	Inorganic Carbon	Total C (LECO)	N	C: N Ratio	OM Carbon	P	CEC	K	Ca	Mg	Na[1]	Base Saturation
		cm		dS/m	%	%	%	%		%	ppm	cmols/kg	cmols/kg				%
07-01	Oi BD	0-11	3.61	0.12	94.77	na	51.83	1.31	39.51	55	29	69.86	1.25	14.16	5.23	0.0	29.55
8/30/2012	Oa BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Oa	11-18	4.28	0.10	60.25	na	34.66	1.54	22.58	58	5	51.32	0.51	9.08	2.85	0.02	24.27
	A BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	A	18-25	4.18	0.06	19.49	na	11.58	0.47	24.57	59	<1	29.02	0.06	3.12	0.91	0.02	14.15
	Bg BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Bg	25-38	4.47	0.06	3.72	na	2.01	0.06	33.17	54	3	9.87	0.03	1.93	0.88	0.03	29.17
	Bg/Ajj BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Bg/Ajj	38-70	4.38	0.05	4.31	na	2.22	0.07	31.81	52	<1	10.21	0.03	1.79	0.80	0.03	25.98
	Bg/Ajjf	70-80	4.59	0.06	10.82	na	5.98	0.21	28.37	55	<1	19.00	0.06	4.67	1.20	0.06	31.55
	Cf	80-100	4.80	0.17	10.08	na	5.79	0.18	32.22	57	<1	15.93	0.08	5.18	1.41	0.14	42.74
	Bgf	40-60	4.57	0.07	7.70	na	4.27	0.12	35.08	55	<1	15.21	0.05	2.61	0.64	0.12	22.48
	Cgf	60-100	5.15	0.11	13.46	na	7.85	0.25	30.84	58	1	20.77	0.04	12.63	0.92	0.07	65.73
07-02 L	Oi BD	0-8	3.53	0.29	92.57	na	52.43	1.23	42.65	57	46	73.47	1.84	9.29	3.81	0.11	20.49
8/30/2012	Oa BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Oa	8-48	4.12	0.12	36.13	na	20.71	0.75	27.61	57	3	46.87	0.41	3.61	1.19	0.03	11.18
	Bg/Ajj BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Bg/Ajj	48-73	4.68	0.06	5.06	na	2.57	0.08	31.75	51	<1	17.39	0.04	3.89	0.80	0.04	27.40
Inclusion	Bgjj BD		na	na	na	na	na	na			na	na	na	na	na	na	na
Inclusion	Bgjj	20-65	4.62	0.05	9.99	na	5.69	0.18	31.06	57	<1	12.28	0.04	4.63	0.97	0.04	46.22
07-03	Oi BD	0-9	4.70	0.26	85.09	na	49.67	1.49	33.32	58	31	94.50	1.80	58.61	6.34	0.01	70.65
8/30/2012	Oe	9-20															
	A BD	10-20	na	na	na	na	na	na			na	na	na	na	na	na	na
	A	10-20	4.75	0.09	13.28	na	7.86	0.37	21.36	59	<1	31.77	0.10	18.65	2.66	0.04	67.53
	Bw1 BD	20-38	na	na	na	na	na	na			na	na	na	na	na	na	na
	Bw1	20-38	6.25	0.06	2.31	na	0.74	0.03	24.33	32	<1	9.37	0.04	7.75	1.47	0.04	99.25
	Ajj BD	38-42	na	na	na	na	na	na			na	na	na	na	na	na	na
	Ajj	38-42	6.52	0.13	8.23	<.01	4.31	0.19	22.52	52	2	23.83	0.05	24.50	3.20	0.05	100
	Bw2	42-65	6.63	0.11	3.23	<.01	1.00	0.06	15.67	31	<1	17.18	0.08	17.13	2.56	0.04	100
	2C	65-115	7.23	0.11	1.03	<.01	0.10	<.01			<1	14.89	0.06	15.77	1.70	0.01	100

Site & Date	Horizon	Depth	pH	E.C.	C Loss on Ignition	Inorganic Carbon	Total C (LECO)	N	C: N Ratio	OM Carbon	P	CEC	K	Ca	Mg	Na[1]	Base Saturation
		cm		dS/m	%	%	%	%		%	ppm	cmols/kg					%
08-01	A BD	0-10	5.01	0.44	60.74	na	34.11	1.84	18.49	56	31	82.60	2.48	34.68	11.64	0.01	59.08
8/31/2012	Bw1 + A BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Bw1	10-18	4.88	0.18	11.80	na	5.85	0.44	13.28	50	2	24.06	0.24	7.99	3.42	0.02	48.47
	A	18-20	4.85	0.25	20.25	na	10.03	0.71	14.22	50	4	24.79	0.26	12.39	4.76	0.01	70.27
	Bw2 BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Bw2	20-40	4.81	0.08	6.15	na	2.67	0.22	11.95	43	<1	14.01	0.04	3.65	1.83	0.02	39.54
	Bg	40-75	4.87	0.05	4.81	na	2.05	0.14	14.43	43	<1	11.24	0.02	2.21	1.21	0.01	30.78
08-02	Oi BD	0-10	4.22	0.16	93.14	na	51.34	1.21	42.38	55	28	89.50	1.66	25.24	7.16	0.00	38.05
8/31/2012	Oe BD	10-15	4.11	0.13	53.06	na	29.74	1.10	27.13	56	18	49.77	0.90	10.63	3.63	0.01	30.48
	A	15-18	4.15	0.08	14.97	na	7.33	0.35	20.91	49	9	22.32	0.23	3.74	1.46	0.00	24.32
	Bw	18-50	5.53	0.04	1.59	na	0.31	0.02	20.66	20	5	5.00	0.05	2.66	1.31	0.00	80.26
	Bg	50-100	5.64	0.05	1.14	na	0.12	0.01	11.46	10	4	4.67	0.05	2.03	1.17	0.02	70.08
08-03 R	Oi BD	0-15	3.58	0.19	95.14	na	52.11	1.17	44.38	55	56	83.07	1.82	15.70	5.54	0.01	27.77
8/31/2012	Bw	15-55	4.34	0.08	6.52	na	3.07	0.20	15.15	47	<1	14.24	0.06	3.56	1.28	0.02	34.55
	Bc	55-80	4.83	0.05	1.64	na	0.57	0.03	19.00	35	1	6.65	0.02	1.62	0.64	0.01	34.45
08-03 L	Oi BD	0-10	4.13	0.23	54.01	na	29.69	1.13	26.19	55	28	29.03	0.75	8.19	2.30	0.00	38.73
8/31/2012	Oe	10-16	4.41	0.18	48.12	na	27.91	0.99	28.06	58	30	47.28	0.85	12.76	3.99	0.01	37.24
	A BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	A	16-20	4.36	0.12	20.54	na	11.18	0.51	21.84	54	8	27.15	0.37	6.61	2.18	0.00	33.75
08-04	Oi BD	0-10	4.43	0.25	94.04	na	52.17	1.52	34.35	55	106	154.24	2.01	37.89	10.56	0.00	32.71
8/31/2012	Oe BD	10-18	5.19	0.35	81.61	na	45.51	1.67	27.26	56	45	97.26	2.09	38.78	9.71	0.17	52.18
	Oa BD		na	na	na	na	na	na		0	na	na	na	na	na	na	na
	Oa	18-26	4.75	0.17	39.33	na	22.56	1.27	17.79	57	8	22.51	0.42	22.63	6.19	0.12	100
	Bw	26-50	4.83	0.08	4.21	na	1.83	0.11	16.45	43	<1	14.09	0.05	4.79	1.63	0.02	46.07
	Bg	50-105	4.69	0.05	2.02	na	0.79	0.03	26.00	39	8	7.80	0.03	2.38	0.90	0.02	42.68

Site & Date	Horizon	Depth	pH	E.C.	C Loss on Ignition	Inorganic Carbon	Total C (LECO)	N	C: N Ratio	OM Carbon	P	CEC	K	Ca	Mg	Na[1]	Base Saturation
		cm		dS/m	%	%	%	%		%	ppm	cmols/kg	cmols/kg				%
09-01	Oi BD	0-4	4.15	0.20	85.49	na	52.10	1.60	32.64	61	76	82.74	1.52	20.60	6.48	0.02	34.60
9/1/2012	A	4-7	4.17	0.09	9.96	na	5.14	0.23	21.91	52	7	20.14	0.23	4.17	1.58	0.03	29.87
	Bw/Bg BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Bw/Bg	7-30	4.74	0.04	4.08	na	1.83	0.09	20.11	45	3	12.14	0.04	3.14	0.89	0.04	33.87
	Bg/Ajj BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Bg/Ajj	30-48	4.78	0.05	6.75	na	3.74	0.16	23.00	55	<1	18	0.04	4.25	1.01	0.06	30.19
	Bg BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Bg	48-59	5.29	0.05	3.17	na	1.24	0.08	15.38	39	8	11.63	0.05	6.25	1.60	0.05	68.39
	2C	59-80	5.66	0.04	2.03	na	0.62	0.04	15.25	30	7	11.12	0.10	7.67	2.14	0.06	89.74
09-02	Bw1	1-7	4.71	0.06	4.74	na	1.80	0.07	25.43	38	<1	13.23	0.09	1.12	0.34	0.06	12.14
9/1/2012	Bw2	7-15	4.95	0.03	2.42	na	0.66	0.01	65.00	27	<1	11.41	0.06	0.97	0.71	0.06	15.79
	2CR	15-50															
09-03	Oi BD	0-7	4.24	0.25	82.92	na	50.74	1.77	28.69	61	97	73.04	2.84	28.57	6.05	0.01	51.29
9/1/2012	Oi BD		na	na	na	na	na	na			na	na	na	na	na	na	na
	Bw/Ajj BD	7-35	5.90	0.11	6.06	na	2.97	0.15	19.47	49	6	22.22	0.09	19.87	2.71	0.07	100
	Bw/Ajj		na	na	na	na	na	na			na	na	na	na	na	na	na
	Bg1 BD	35-50	7.39	0.31	4.62	0.13	2.31	0.19	12.00	50	20	14.53	0.06	35.26	2.29	0.06	100
	Bg1	35-50	na	na	na	na	na	na			na	na	na	na	na	na	na
	Bg2 BD	50-82	7.73	0.67	3.60	0.89	2.45	0.13	18.69	68	12	10.53	0.07	53.31	3.96	0.13	100
	Cf	82-100	7.45	2.26	5.49	0.23	2.94	0.18	16.06	53	19	15.09	0.12	44.47	6.20	0.30	100
10-01	A	0-3	4.90	0.07	9.33	na	5.41	0.23	23.13	58	5	15.27	0.24	2.11	0.53	0.03	19.07
9/2/2012	Bw	3-8	5.10	0.03	4.86	na	2.31	0.10	22.80	48	4	7.04	0.10	0.33	0.09	0.01	7.56
	BC	8-25	5.44	0.03	0.42	na	0.17	<.01	17.02	40	12	0.33	0.01	0.01	0.00	0.01	9.72
	CR	25-50															

Site & Date	Horizon	Depth	pH	E.C.	C Loss on Ignition	Inorganic Carbon	Total C (LECO)	N	C: N Ratio	OM Carbon	P	CEC	K	Ca	Mg	Na[1]	Base Saturation
		cm		dS/m	%	%	%	%		%	ppm	cmols/kg					%
10-02	Oi BD	0-16	6.03	0.50	89.21	na	53.05	1.63	32.64	59	56	107.18	2.58	83.02	27.61	0.01	100
9/2/2012	Oa BD	16-30	6.95	0.35	58.57	0.05	35.32	1.99	17.78	60	12	138.24	0.32	105.03	29.98	0.07	97.95
	A	30-38	6.66	0.21	19.65	0.02	10.82	0.68	15.95	55	2	58.64	0.12	48.84	14.29	0.05	100
	Bg1	38-47	6.30	0.10	5.72	na	2.92	0.18	15.94	51	<1	20.06	0.07	16.93	5.74	0.05	100
	Bg2 Red	47-55	6.71	0.18	11.63	0.01	5.96	0.34	17.52	51	<1	22.55	0.07	32.51	6.95	0.05	100
	Bg2 Grey	47-55	6.47	0.09	6.96	<.01	3.81	0.21	17.81	55	<1	24.01	0.07	21.10	4.71	0.04	100
	BC	55-70	6.81	0.14	6.91	<.01	3.70	0.20	18.20	54	1	21.76	0.08	23.28	4.87	0.05	100
	Ab/Cf	70-85	6.81	0.25	7.42	0.04	3.95	0.24	16.13	53	2	27.13	0.07	26.57	5.28	0.06	100
	Cf	85 - 100	6.97	0.26	5.39	0.03	2.91	0.16	17.88	54	5	18.33	0.09	23.13	5.19	0.06	100
10-03	Oi BD	0 -10	4.27	0.16	94.01	na	53.38	1.25	42.53	57	66	82.98	1.95	40.46	12.08	0.00	65.67
9/2/2012	Oe BD	10 18	6.77	0.28	89.14	0.03	53.09	1.59	33.44	60	29	115.42	1.08	94.44	28.21	0.11	100
	Oa BD		6.58	na	na	na	na	na			na	na	na	na	na	na	na
	Oa	18 - 22	6.39	0.21	66.10	na	40.61	2.11	19.28	61	10	177.03	0.30	99.07	32.56	0.12	74.59
	A	22 - 32	6.30	0.15	12.73	na	6.74	0.38	17.70	53	6	42.85	0.06	31.17	9.18	0.05	94.41
	Bg	32 - 38	6.32	0.08	3.96	na	1.87	0.18	10.28	47	4	15.95	0.04	13.82	3.99	0.04	100
	Ab/C	38 - 50	6.07	0.17	13.88	na	8.43	0.49	17.36	61	4	49.08	0.07	40.37	9.71	0.08	100
	Cf	50- 80															

1. For Sodium (Na) values of 0.00 were reported as <0.01 and entreredas0.0001 for purposes of calculation
2. na=not applicable-either to organic or no sample

Summit
Saddle
Shoulder
Back Slope
Foot Slope/ Terrace

APPENDIX E. Extractable Iron – Aluminum of the toposequence study sites in the Steese and White Mountains area, Alaska

Site & Date	Layer ID		Ammonium Oxalate			Dithionite-Citrate			Sodium-Pyrophosphate			PLOT	PLOT
			Fe	Al	Si	Fe	Al	Mn	Fe	Al	AD/OD	Feo/Fed	Alp/Alo
		cm	%	%	%	%	%	%	%	%			
01-01	A	0-5	0.88	0.45	0.09	1.32	0.51	0.02	0.45	0.25	1.020	0.667	0.568
8/24/2012	Bw1	5-11	1.01	0.76	0.20	1.53	0.78	0.01	0.41	0.36	1.017	0.660	0.467
	Bw2	11-18	0.60	0.60	0.18	0.97	0.48	0.03	0.09	0.20	1.011	0.615	0.339
	Bw3	15-35	0.58	0.53	0.15	0.91	0.41	0.03	0.11	0.18	1.010	0.633	0.337
	CR	35-50											
01-02	Oi BD		na	na	na	na	na	na	na	na	1.079		
8/24/2012	Oi	0-5	na	na	na	na	na	na	na	na	1.093		
	Oe	5-10	na	na	na	na	na	na	na	na	1.082		
	Oa	10-15	na	na	na	na	na	na	na	na	1.061		
	Oa BD		na	na	na	na	na	na	na	na	na		
	Bw	15-25	1.57	0.62	0.10	1.47	0.58	0.01	0.82	0.33	1.030	1.063	0.533
	Bw BD		na	na	na	na	na	na	na	na	na		
	Bg	15-25	0.42	0.24	0.04	0.56	0.13	<0.01	0.17	0.08	1.014	0.745	0.333
	CR	25-35											
01-03	Oi Bd	0-9	na	na	na	na	na	na	na	na	1.085		
8/24/2012	Oa Bd		na	na	na	na	na	na	na	na	na		
	Oa	9-23	na	na	na	na	na	na	na	na	1.084		
	Bg1 BD		na	na	na	na	na	na	na	na	na		
	Bg1	23-38	1.23	0.22	0.15	0.77	0.08	<0.01	0.30	0.04	1.011	1.605	0.182
	Bg2 BD		na	na	na	na	na	na	na	na	na		
	Bg2	38-52	1.61	0.23	0.12	1.03	0.11	0.02	0.50	0.06	1.016	1.574	0.261
	Cg/Oajjf	52-80	1.31	0.24	0.13	0.78	0.11	0.03	0.60	0.08	1.018	1.675	0.333

Site & Date	Layer ID		Ammonium Oxalate			Dithionite-Citrate			Sodium-Pyrophosphate			PLOT	PLOT
			Fe	Al	Si	Fe	Al	Mn	Fe	Al	AD/OD	Feo/Fed	Alp/Alo
		cm	%	%	%	%	%	%	%	%			
	Oi BD	0-12	na	na	na	na	na	na	na	na	1.074		
8/24/2012	Oe BD	12-18	na	na	na	na	na	na	na	na	1.092		
	Bw1	18-25	0.97	0.25	0.09	0.91	0.19	0.04	0.51	0.09	1.013	1.067	0.360
	Bw2	25-32	0.97	0.17	0.06	0.74	0.12	0.01	0.45	0.07	1.009	1.315	0.412
	Bg	32-38	0.49	0.19	0.05	0.43	0.14	<0.01	0.24	0.08	1.009	1.140	0.421
	Cf/Wf	38-80	0.98	0.22	0.07	0.94	0.18	0.01	0.45	0.09	1.011	1.043	0.409
02-01	Oi	0-12	na	na	na	na	na	na	na	na	1.084		
8/25/2012	Oa	12-28	na	na	na	na	na	na	na	na	1.072		
	Bw	28-40	0.70	0.17	0.05	1.19	0.16	<0.01	0.19	0.06	1.007	0.593	0.353
	A	0-5	0.69	0.15	0.05	1.10	0.16	<0.01	0.23	0.07	1.010	0.624	0.467
	Bw1	5-18	0.70	0.15	0.04	1.08	0.14	<0.01	0.18	0.06	1.007	0.654	0.400
	Bw2	18-42	0.78	0.19	0.04	1.22	0.16	<0.01	0.23	0.07	1.007	0.636	0.368
	BC	42-80	0.83	0.20	0.04	1.16	0.16	<0.01	0.24	0.07	1.008	0.713	0.350
02-02	Oi BD	0-14	na	na	na	na	na	na	na	na	1.082		
8/25/2012	Oa Bd		na	na	na	na	na	na	na	na	na		
	Oa	14-23	na	na	na	na	na	na	na	na	1.070		
	A VD		na	na	na	na	na	na	na	na	na		
	A	23-30	na	na	na	na	na	na	na	na	1.049		
	Bw/Ajj BD		na	na	na	na	na	na	na	na	na		
	Bw/Ajj	30-48	0.77	0.23	0.06	0.77	0.21	<0.01	0.45	0.11	1.020	1.000	0.478
	A/BwjjF	48-58	1.08	0.28	0.14	1.00	0.26	<0.01	0.73	0.14	1.027	1.082	0.519
	Cf	58-80											
02-03	Oi1	0-36	na	na	na	na	na	na	na	na	1.090		
8/25/2012	Oi2	26-44	na	na	na	na	na	na	na	na	1.106		
	Oaf	44-60	na	na	na	na	na	na	na	na	1.086		
	Cf												

Site & Date	Layer ID		Ammonium Oxalate			Dithionite-Citrate			Sodium-Pyrophosphate			PLOT	PLOT
			Fe	Al	Si	Fe	Al	Mn	Fe	Al	AD/OD	Feo/Fed	Alp/Alo
		cm	%	%	%	%	%	%	%	%			
	Ab	25-33	0.91	0.31	0.13	1.37	0.22	<0.01	0.32	0.11	1.015	0.667	0.355
	Bwb	33-55	0.94	0.19	0.05	1.36	0.16	0.01	0.23	0.07	1.010	0.689	0.368
03-01	Oi BD	0-8	na	na	na	na	na	na	na	na	1.097		
8/26/2012	Oa BD		na	na	na	na	na	na	na	na	na		
	A1	8-15	na	na	na	na	na	na	na	na	1.075		
	A BD		na	na	na	na	na	na	na	na	na		
	A2	15-21	na	na	na	na	na	na	na	na	1.060		
	Oajj	21-25	na	na	na	na	na	na	na	na	1.089		
	Bw	25-40	0.81	0.25	0.07	1.33	0.21	0.04	0.33	0.09	1.013	0.611	0.360
	Bg	40-60	0.44	0.13	0.07	1.68	0.12	0.06	0.08	0.02	1.007	0.263	0.154
03-02	Oi BD	0-8	na	na	na	na	na	na	na	na	1.080		
8/26/2012	Oe BD	8-13	na	na	na	na	na	na	na	na	1.088		
	Oa BD		na	na	na	na	na	na	na	na	na		
	A	13-22	na	na	na	na	na	na	na	na	1.047		
	Bg/Oajj BD		na	na	na	na	na	na	na	na	na		
	Bg/Oajj	22-46	1.03	0.21	0.11	1.00	0.14	0.03	0.48	0.08	1.019	1.031	0.381
	Ajj BD		na	na	na	na	na	na	na	na	na		
	Ajj	22-30	3.21	0.38	0.16	2.62	0.37	1.05	1.21	0.17	1.046	1.226	0.444
	Bg/Oajj	30-46	2.44	0.30	0.08	1.95	0.27	0.02	1.49	0.15	1.044	1.251	0.483
	Cgf	46-80	1.11	0.17	0.08	0.89	0.08	0.02	0.35	0.05	1.011	1.250	0.294
03-03R	Oi BD	0-8	na	na	na	na	na	na	na	na	1.084		
8/26/2012	Oe BD	8-18	na	na	na	na	na	na	na	na	1.057		
	Bw1	18-75	0.88	0.20	0.06	1.06	0.13	0.02	0.34	0.07	1.011	0.829	0.350
	Bw2	75-80	0.82	0.19	0.06	0.90	0.10	0.02	0.21	0.07	1.009	0.910	0.368

Site & Date	Layer ID		Ammonium Oxalate			Dithionite-Citrate			Sodium-Pyrophosphate			PLOT	PLOT
			Fe	Al	Si	Fe	Al	Mn	Fe	Al	AD/OD	Feo/Fed	Alp/Alo
		cm	%	%	%	%	%	%	%	%			
03-03L	Oi BD	0-20	na	na	na	na	na	na	na	na	1.087		
8/26/2012	Oajj BD		na	na	na	na	na	na	na	na	1.108		
	Oajj	20-60	na	na	na	na	na	na	na	na	1.083		
	Cgf	60-80	1.17	0.43	0.22	1.10	0.45	0.05	0.80	0.22	1.043	1.067	0.512
04-01	A	0-5	0.69	0.38	0.34	1.03	0.25	0.02	0.28	0.14	1.013	0.667	0.368
8/27/2012	Bw1	5-20	0.54	0.28	0.18	1.00	0.15	0.01	0.20	0.09	1.009	0.545	0.321
	Bw2	20-35	1.47	0.97	0.51	1.89	0.59	0.02	0.20	0.25	1.016	0.780	0.263
	BC	35-55	0.48	0.35	0.36	0.93	0.13	0.04	0.09	0.06	1.006	0.522	0.171
	Cf												
04-02R	Oe	0-3	na	na	na	na	na	na	na	na	1.055		
8/27/2012	Ajj	3-6	1.21	0.27	0.27	1.10	0.11	0.01	0.38	0.07	1.017	1.102	0.259
	Bg/Bwjj	6-42	0.76	0.16	0.13	0.66	0.05	0.01	0.11	0.04	1.008	1.154	0.250
	Bg/Bgjj	42-50	0.83	0.17	0.06	0.84	0.07	<0.01	0.30	0.07	1.010	0.988	0.412
	Cg	50-120	0.68	0.14	0.09	0.98	0.07	0.04	0.09	0.03	1.008	0.691	0.214
04-02L	A BD		na	na	na	na	na	na	na	na	na		
8/27/2012	A	0-20	na	na	na	na	na	na	na	na	1.080		
	Ajj	0-30	0.84	0.19	0.17	0.66	0.06	0.05	0.26	0.04	1.018	1.277	0.211
	Bg	20-40	0.48	0.17	0.06	0.44	0.08	<0.01	0.24	0.08	1.009	1.091	0.471
	Oejj	20-60	na	na	na	na	na	na	na	na	1.065		
	Oajj	60-80	0.89	0.19	0.16	0.72	0.07	0.04	0.37	0.06	1.025	1.243	0.316
04-03	Oi BD	0-22	na	na	na	na	na	na	na	na	1.081		
8/27/2012	Oi2 BD	22-30	na	na	na	na	na	na	na	na	1.098		
	A	30-35	na	na	na	na	na	na	na	na	1.056		
	Bg	35-55	0.65	0.17	0.05	0.71	0.08	<0.01	0.33	0.08	1.011	0.914	0.471
	Oajj	55-60	na	na	na	na	na	na	na	na	1.058		
	Bg/Oajj	60-70											
	Cgf	70-80	1.19	0.16	0.06	1.06	0.06	0.01	0.39	0.05	1.009	1.124	0.313

Site & Date	Layer ID		Ammonium Oxalate			Dithionite-Citrate			Sodium-Pyrophosphate			PLOT	PLOT
			Fe	Al	Si	Fe	Al	Mn	Fe	Al	AD/OD	Feo/Fed	Alp/Alo
		cm	%	%	%	%	%	%	%	%			
04-04	Oa BD	0-12	na	na	na	na	na	na	na	na	1.083		
8/27/2012	Bg	12-20	0.64	0.17	0.05	0.66	0.10	<0.01	0.46	0.09	1.013	0.969	0.529
	Ab	20-30	0.65	0.17	0.05	0.71	0.12	<0.01	0.42	0.09	1.014	0.914	0.529
	Bgb	30-47	0.70	0.12	0.05	0.83	0.06	0.01	0.25	0.05	1.008	0.841	0.417
	Cg	47-60	0.17	0.05	0.03	0.92	0.06	0.03	0.05	0.02	1.006	0.187	0.400
05-01	Oi BD	0-20	na	na	na	na	na	na	na	na	1.074		
8/28/2012	Oe BD	30-37	na	na	na	na	na	na	na	na	1.109		
	Bw BD		na	na	na	na	na	na	na	na	na		
	Bw	37-50	0.23	0.12	0.02	0.20	0.05	<0.01	0.14	0.06	1.010	1.150	0.500
	Cg/Oajj	50-80	na	na	na	na	na	na	na	na	1.035		
05-02	Oi BD	0-8	na	na	na	na	na	na	na	na	1.096		
8/28/2012	Oe BD	8-16	na	na	na	na	na	na	na	na	1.110		
	Oa BD	16-22	na	na	na	na	na	na	na	na	1.164		
	O'e BD	22-32	na	na	na	na	na	na	na	na	1.085		
	Bg BD		na	na	na	na	na	na	na	na	na		
	Bg	32-48	0.36	0.22	0.06	0.26	0.10	<0.01	0.20	0.11	1.015	1.346	0.500
	Cgf	48-80	8.59	0.30	0.19	8.34	0.22	<0.01	5.30	0.17	1.076	1.030	0.571
05-03 R	Oi	0-8	na	na	na	na	na	na	na	na	1.087		
8/28/2012	Bg1	8-15	1.03	0.23	0.03	1.20	0.14	0.01	0.54	0.09	1.012	0.857	0.391
	Bg/Ajj	15-50	1.06	0.22	0.15	1.34	0.16	0.02	0.62	0.11	1.012	0.795	0.500
	Ajj	25-40	na	na	na	na	na	na	na	na	1.054		
	Oajj	50-55	2.20	0.38	0.08	2.35	0.36	0.09	1.42	0.22	1.029	0.939	0.568
	Bg2	55-70	0.80	0.17	0.04	1.10	0.10	0.01	0.45	0.08	1.011	0.725	0.471
	Cg/Ajjf	70-100	1.00	0.18	0.04	1.16	0.11	<0.01	0.50	0.08	1.014	0.868	0.444
05-03 L	Oi	42-50	na	na	na	na	na	na	na	na	1.095		
05-03 L	Oe BD	50-65	na	na	na	na	na	na	na	na	1.126		
05-03 L	Oa BD	65-70	na	na	na	na	na	na	na	na	1.153		
05-03 C	Oaf	70-80	na	na	na	na	na	na	na	na	1.054		

Site & Date	Layer ID		Ammonium Oxalate			Dithionite-Citrate			Sodium-Pyrophosphate			PLOT	PLOT
			Fe	Al	Si	Fe	Al	Mn	Fe	Al	AD/OD	Feo/Fed	Alp/Alo
		cm	%	%	%	%	%	%	%	%			
05-04	Oi BD	0-12	na	na	na	na	na	na	na	na	1.100		
8/28/2012	Oa BD	12-18	na	na	na	na	na	na	na	na	1.086		
	Oa	18-20	na	na	na	na	na	na	na	na	1.070		
	Bw	20-38	0.71	0.11	0.02	1.19	0.07	<0.01	0.41	0.04	1.009	0.593	0.364
	Bg1	38-41	0.37	0.11	0.03	0.72	0.06	<0.01	0.28	0.06	1.007	0.514	0.545
	Bg2 BD		na	na	na	na	na	na	na	na	na		
	Bg2	41-60	0.91	0.29	0.10	1.30	0.06	0.01	0.35	0.04	1.007	0.698	0.138
	Cf	60-80	0.80	0.10	0.01	1.40	0.07	0.01	0.32	0.05	1.006	0.568	0.500
06-01	Oi BD	0-35	na	na	na	na	na	na	na	na	1.087		
8/29/2012	Oe BD	35-38	na	na	na	na	na	na	na	na	1.092		
	Bw	38-42	0.72	0.17	0.04	0.86	0.10	0.03	0.33	0.07	1.011	0.835	0.412
	Bg	42.53	0.69	0.18	0.05	0.85	0.07	0.02	0.50	0.13	1.011	0.810	0.722
	Cgf	53-80	0.72	0.16	0.05	0.80	0.07	0.03	0.47	0.12	1.010	0.899	0.750
06-02	Oi	0-8	na	na	na	na	na	na	na	na	1.080		
8/29/2012	O\A	8-15	na	na	na	na	na	na	na	na	1.037		
	Bw	16-35	1.16	0.29	0.07	1.15	0.16	0.04	0.76	0.13	1.020	1.009	0.464
	Bg/Bw	35-51	1.10	0.25	0.05	1.14	0.16	0.05	0.65	0.12	1.018	0.964	0.480
	Bw/Ajj	51-70	1.03	0.30	0.06	1.16	0.23	0.02	0.71	0.16	1.024	0.894	0.552
	Bg	70-82	0.83	0.20	0.05	0.85	0.10	0.01	0.34	0.07	1.011	0.976	0.350
	Cgf	82-100	0.57	0.14	0.03	0.78	0.11	0.01	0.30	0.07	1.008	0.740	0.500
06-03	Oi	0-9	na	na	na	na	na	na	na	na	1.087		
8/29/2012	Oe BD	9-17	na	na	na	na	na	na	na	na	1.116		
	Oa	17-22	na	na	na	na	na	na	na	na	1.070		
	A	22-26	0.98	0.23	0.06	1.24	0.15	0.06	0.48	0.09	1.023	0.793	0.409
	Bg/Oajj L	26-50	0.95	0.14	0.03	1.19	0.09	0.02	0.36	0.05	1.010	0.797	0.357
	Bg/Oajj R	50-75	0.77	0.14	0.03	0.98	0.08	0.01	0.30	0.05	1.008	0.784	0.357
	Cgf	75-100	1.23	0.16	0.04	1.63	0.11	0.05	0.39	0.05	1.009	0.758	0.313

Site & Date	Layer ID		Ammonium Oxalate			Dithionite-Citrate			Sodium-Pyrophosphate			PLOT	PLOT
			Fe	Al	Si	Fe	Al	Mn	Fe	Al	AD/OD	Feo/Fed	Alp/Alo
		cm	%	%	%	%	%	%	%	%			
07-01	Oi BD	0-11	na	na	na	na	na	na	na	na	1.067		
8/30/2012	Oa BD		na	na	na	na	na	na	na	na	na		
	Oa	11-18	na	na	na	na	na	na	na	na	1.066		
	A BD		na	na	na	na	na	na	na	na	na		
	A	18-25	0.79	0.33	0.08	0.74	0.26	<.01	0.59	0.18	1.025	1.069	0.563
	Bg BD		na	na	na	na	na	na	na	na	na		
	Bg	25-38	0.39	0.18	0.05	0.37	0.07	<.01	0.17	0.07	1.008	1.054	0.389
	Bg/Ajj BD		na	na	na	na	na	na	na	na	na		
	Bg/Ajj	38-70	0.59	0.17	0.03	0.50	0.07	<.01	0.28	0.08	1.009	1.160	0.471
	Bg/Ajjf	70-80	1.66	0.20	0.06	1.44	0.09	<.01	0.93	0.11	1.017	1.148	0.550
	Cf	80-100	1.30	0.17	0.05	1.38	0.08	<.01	0.75	0.09	1.017	0.941	0.529
07-02 R	Oi BD	0-30	na	na	na	na	na	na	na	na	1.077		
8/30/2012	Oe BD	30-40	na	na	na	na	na	na	na	na	1.092		
	Bgf	40-60	1.33	0.20	0.05	1.25	0.09	<.01	0.68	0.09	1.013	1.065	0.450
	Cgf	60-100	1.20	0.24	0.08	1.25	0.14	0.01	0.76	0.13	1.018	0.959	0.542
07-02 L	Oi BD	0-8	na	na	na	na	na	na	na	na	1.078		
8/30/2012	Oa BD		na	na	na	na	na	na	na	na	na		
	Oa	8-48	na	na	na	na	na	na	na	na	1.042		
	Bg/Ajj BD		na	na	na	na	na	na	na	na	na		
	Bg/Ajj	48-73	1.93	0.22	0.05	0.83	0.07	<.01	1.04	0.12	1.010	2.329	0.545
Inclusion	Bgjj BD		na	na	na	na	na	na	na	na	na		
Inclusion	Bgjj	20-65	0.76	0.17	0.07	1.83	0.13	<.01	0.39	0.08	1.017	0.417	0.471

Site & Date	Layer ID		Ammonium Oxalate			Dithionite-Citrate			Sodium-Pyrophosphate			PLOT	PLOT
			Fe	Al	Si	Fe	Al	Mn	Fe	Al	AD/OD	Feo/Fed	Alp/Alo
		cm	%	%	%	%	%	%	%	%			
07-03	Oi BD	0-9	na	na	na	na	na	na	na	na	1.096		
8/30/2012	Oe	9-20											
	A BD	10-20	na	na	na	na	na	na	na	na	na		
	A	10-20	0.94	0.19	0.04	1.68	0.15	0.01	0.61	0.11	1.022	0.561	0.579
	Bw1 BD	20-38	na	na	na	na	na	na	na	na	na		
	Bw1	20-38	1.03	0.12	0.04	2.19	0.10	0.02	0.35	0.05	1.007	0.470	0.417
	Ajj BD	38-42	na	na	na	na	na	na	na	na	na		
	Ajj	38-42	1.11	0.19	0.06	2.07	0.14	0.03	0.48	0.08	1.018	0.537	0.421
	Bw2	42-65	1.14	0.17	0.10	3.25	0.14	0.08	0.28	0.04	1.012	0.352	0.235
	2C	65-115	1.05	0.13	0.06	0.90	0.04	0.01	0.03	0.01	1.014	1.169	0.077
08-01	A BD	0-10	na	na	na	na	na	na	na	na	1.079		
8/31/2012	Bw1 + A BD		na	na	na	na	na	na	na	na	na		
	Bw1	10-18	1.75	0.35	0.08	2.15	0.30	0.22	1.30	0.19	1.024	0.814	0.559
	A	18-20	1.98	0.47	0.09	2.42	0.47	0.46	1.48	0.28	1.037	0.820	0.600
	Bw2 BD		na	na	na	na	na	na	na	na	na		
	Bw2	20-40	1.60	0.30	0.07	2.02	0.23	0.06	1.03	0.15	1.016	0.789	0.500
	Bg	40-75	1.29	0.25	0.03	1.59	0.19	0.01	0.79	0.14	1.013	0.809	0.560
08-02	Oi BD	0-10	na	na	na	na	na	na	na	na	1.091		
8/31/2012	Oe BD	10-15	na	na	na	na	na	na	na	na	1.054		
	A	15-18	0.70	0.21	0.08	1.52	0.20	0.02	0.49	0.10	1.020	0.463	0.476
	Bw	18-50	0.43	0.06	<.01	2.38	0.07	0.02	0.13	0.03	1.005	0.181	0.500
	Bg	50-100	0.11	0.03	<.01	3.12	0.05	0.03	0.05	0.01	1.003	0.035	0.333

Site & Date	Layer ID		Ammonium Oxalate			Dithionite-Citrate			Sodium-Pyrophosphate			PLOT	PLOT
			Fe	Al	Si	Fe	Al	Mn	Fe	Al	AD/OD	Feo/Fed	Alp/Alo
		cm	%	%	%	%	%	%	%	%			
08-03 R	Oi BD	0-15	na	na	na	na	na	na	na	na	1.077		
8/31/2012	Bw	15-55	0.91	0.18	0.05	1.29	0.13	0.02	0.58	0.08	1.015	0.709	0.444
	Bc	55-80	0.80	0.12	0.05	1.29	0.07	0.01	0.29	0.05	1.006	0.625	0.417
08-03 L	Oi BD	0-10	na	na	na	na	na	na	na	na	1.049		
8/31/2012	Oe	10-16	na	na	na	na	na	na	na	na	1.047		
	A BD		na	na	na	na	na	na	na	na	na		
	A	16-20	0.61	0.18	0.06	1.01	0.21	0.03	0.41	0.08	1.024	0.606	0.444
08-04	Oi BD	0-10	na	na	na	na	na	na	na	na	1.085		
8/31/2012	Oe BD	10-18	na	na	na	na	na	na	na	na	1.099		
	Oa BD		na	na	na	na	na	na	na	na	na		
	Oa	18-26	na	na	na	na	na	na	na	na	1.057		
	Bw	26-50	1.05	0.18	0.10	1.50	0.11	0.07	0.61	0.08	1.010	0.698	0.444
	Bg	50-105	0.69	0.61	0.03	1.28	0.07	0.01	0.25	0.05	1.007	0.543	0.082
09-01	Oi BD	0-4	na	na	na	na	na	na	na	na	1.079		
9/1/2012	A	4-7	0.91	0.32	0.19	1.12	0.19	0.01	0.49	0.12	1.020	0.809	0.387
	Bw/Bg		na	na	na	na	na	na	na	na	na		
	Bw/Bg	7-30	0.89	0.22	0.03	1.16	0.14	0.01	0.36	0.11	1.012	0.765	0.500
	Bg/Ajj		na	na	na	na	na	na	na	na	na		
	Bg/Ajj	30-48	0.87	0.24	0.03	1.03	0.16	0.01	0.48	0.14	1.016	0.851	0.583
	Bg BD		na	na	na	na	na	na	na	na	na		
	Bg	48-59	0.67	0.19	0.04	1.00	0.11	0.01	0.27	0.08	1.011	0.667	0.421
	2C	59-80	0.44	0.13	0.05	1.52	0.11	0.02	0.11	0.04	1.009	0.291	0.308
09-02	Bw1	1-7	1.20	0.39	0.04	1.65	0.23	<.01	0.22	0.18	1.013	0.724	0.474
9/1/2012	Bw2	7-15	1.22	0.38	0.12	1.65	0.20	0.01	0.07	0.11	1.013	0.736	0.289
	2Cr	15-50											

Site & Date	Layer ID		Ammonium Oxalate			Dithionite-Citrate			Sodium-Pyrophosphate			PLOT	PLOT
			Fe	Al	Si	Fe	Al	Mn	Fe	Al	AD/OD	Feo/Fed	Alp/Alo
		cm	%	%	%	%	%	%	%	%			
09-03	Oi BD	0-7	na	na	na	na	na	na	na	na	1.066		
9/1/2012	Oi BD		na	na	na	na	na	na	na	na	na		
	Bw/Ajj BD		0.85	0.23	0.10	1.12	0.15	0.02	0.38	0.09	1.016	0.764	0.391
	Bw/Ajj		na	na	na	na	na	na	na	na	na		
	Bg1 BD	35-50	0.80	0.16	0.11	0.93	0.09	0.02	0.15	0.03	1.012	0.859	0.188
	Bg1	35-50	na	na	na	na	na	na	na	na	na		
	Bg2 BD	50-82	0.70	0.15	0.11	0.91	0.08	0.03	0.10	0.04	1.009	0.767	0.267
	Cf	82-100	1.16	0.19	0.13	1.10	0.09	0.03	0.41	0.04	1.016	1.056	0.211
10-01	A	0-3	0.88	0.36	0.05	1.21	0.29	0.01	0.19	0.17	1.017	0.731	0.486
9/2/2012	Bw	3-8	0.73	0.59	0.11	0.96	0.47	0.01	0.14	0.28	1.015	0.758	0.483
	BC	8-25	0.04	0.07	<.01	0.07	0.10	<.01	0.02	0.05	1.001	0.571	0.714
	CR	25-50											
10-02	Oi BD	0-16	na	na	na	na	na	na	na	na	1.113		
9/2/2012	Oa BD	16-30	na	na	na	na	na	na	na	na	1.110		
	A	30-38	1.15	0.22	0.11	1.08	0.10	0.18	0.50	0.20	1.043	1.058	0.905
	Bg1	38-47	0.89	0.24	0.15	0.72	0.07	<.01	0.36	0.11	1.016	1.239	0.458
	Bg2 Red	47-55	5.12	0.21	0.16	5.96	0.08	0.05	1.91	0.10	1.031	0.860	0.500
	Bg2 Grey	47-55	0.98	0.23	0.14	0.98	0.08	0.01	0.40	0.09	1.018	1.000	0.391
	BC	55-70	0.69	0.22	0.12	0.64	0.07	0.01	0.33	0.10	1.018	1.079	0.455
	Ab/Cf	70-85	0.99	0.22	0.17	0.88	0.07	0.02	0.41	0.09	1.020	1.128	0.409
	Cf	85 - 100	0.82	0.22	0.19	0.96	0.08	0.01	0.32	0.07	1.017	0.862	0.318
10-03	Oi BD	0 -10	na	na	na	na	na	na	na	na	1.082		
9/2/2012	Oe BD	10 18	na	na	na	na	na	na	na	na	1.118		
	Oa BD		na	na	na	na	na	na	na	na	na		
	Oa	18 - 22	na	na	na	na	na	na	na	na	1.121		
	A	22 - 32	0.93	0.23	0.07	0.83	0.12	0.06	0.46	0.11	1.030	1.111	0.500
	Bg	32 - 38	0.66	0.16	0.11	1.12	0.09	0.01	0.28	0.07	1.013	0.586	0.438
	Ab/C	38 - 50	0.99	0.25	0.10	1.00	0.13	0.02	0.51	0.11	1.033	0.990	0.458